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No. 4, 1979

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IMMUNOBIOLOGICAL REACTIVITY OF THE BODY UNDER HYPERBARIC AND HYPOBARIC CONDITIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 3-7

[Article by A. S. Kaplanskiy, submitted 14 Apr 78]

[Text] In the course of man's conquest of space and oceans, he has to use an artificial habitat for a long time, and it often differs substantially in its parameters from the environment to which he adapted in the course of phylogenetic and ontogenetic development. The uniqueness of the new living conditions consists of the fact that man or a group of people must live and work in complete or partial isolation from the rest of the world, in sealed areas of limited size, using gas mixtures for respiration that differ from the composition of earth's atmosphere, with exposure to high and low pressures, sharp pressure fluctuations, etc. Yet, it is a known fact now [1-8] that isolation of an individual or group of individuals alone (not to mention other factors) leads to simplification of microflora, increase in aggressiveness thereof and increase in contamination of the habitat by microorganisms. All this leads to onset of autoinfectious diseases and cross infections, the adverse consequences of which to the inhabitants of spacecraft and autonomous underwater habitats would be difficult to exaggerate. If we consider that the state of man's defense systems also plays a substantial role in development of infectious diseases, it becomes obvious that there is a need to investigate the effects of different environmental factors on immunobiological reactivity of the body. The above-mentioned extreme factors, the effects of which on the body have not been sufficiently studied, include, first of all, high and low pressure.

In this work, an effort was made to sum up the few data existing in the literature concerning the effects of hyperbaric and hypobaric gas mixtures on resistance to infections and immunobiological reactivity of the body. It must be noted that, for the purpose of differentiation between the effects of high and low pressure per os, we did not include studies in which partial oxygen pressure (PO_2) in the gas mixture reached levels that had a toxic effect, as well as studies, in which there could have been manifestation of narcotic effects of inert gases.

Hyperbarism: The first information about the adverse effect of gas mixtures at high pressure on man's resistance to conditionally pathogenic microflora were obtained in studies of divers, for whom there was a drastic increase in incidence of colds [9] after numerous and, particularly, deep dives. These findings were confirmed in studies of the crews of the Chernomor and Sealab-2 submarines, who spent a long tome in a hyperbaric nitrogen and oxygen or helium and oxygen environment at depths of 15, 25 and 62 m. During their stay in the submarine abodes, the aquanauts often complained of appearance of suppurative skin lesions, dermatitis and eczema of the external auditory meatus, catarrhs of the respiratory tract [10-14]. It remained unclear as to whether onset of these diseases in aquanauts and divers was related to the adverse effect of hyperbaric gas mixtures or other factors instrumental in development of infectious processes (increased humidity, high or low ambient temperature, microbial contamination of habitat, emotional stress). Experimental studies of animals, in the course of which it was demonstrated that pneumonia induced by influenza virus or Kelbsiella pneumonia occurs in a much severe form in mice subjected to a hyperbaric helium and oxygen environment and involves a higher incidence of death than at normal barometric pressure, also failed to clarify this question completely [15-18]. In the opinion of some authors [15, 17, 18], the adverse effect of a hyperbaric environment on the course of an infectious process is attributable to overcooling of the animals as a result of increased heat transfer in a helium and oxygen atmosphere (no increase in severity of pneumonia in mice in a hyperbaric helium and oxygen environment was observed when the temperature in the pressure chamber was raised to 35°C), whereas other authors [16] relate the more severe course of illness to the direct effect of hyperbaric helium on the animals, since elevation of temperature in the pressure chamber to 35°C in their experiments did not have a beneficial effect on the course of influenzal pneumonia in mice. Data indicative of the deleterious effect of long-term exposure to a helium and oxygen environment at a pressure of 35 kgf/cm^2 on animal resistance to endogenous microflora were obtained in experiments on rabbits, who developed skin lesions starting on the 5th-6th day in the pressure chamber [8, 19]. It is assumed that appearance of skin lesions in rabbits is related to their exposure to a set of factors: higher density of environment, more intensive heat transfer, activation of endogenous microflora and the latter is considered to play a rather important role, since there was a significant decline of morbidity after improvement of the hygienic conditions.

However, it should be noted that, along with data indicative of aggravation of diseases in hyperbaric environments, there are also observations that do not corroborate this finding. For example, in an aquanaut who contracted epideic viral parotitis during a stay in a a helium and oxygen environment at a pressure equivalent to a depth of 180 m, the disease progressed in the same was as at normal pressure, and there was no impairment of production of immune globulins [20].

In spite of the contradiction of data, most researchers do find that hyperbaric nigrogen and oxygen and helium and oxygen environments at high pressure have a deleterious effect on development and course of infectious and inflammatory processes.

Of course, the higher incidence of colds among divers and aquanauts prompted researchers to investigate the state of the body's defense systems responsible for resistance to infectious agents. In the course of these studies, it was established that there is depression of natural immunity in divers and aquanauts, and this is particularly distinct when diving to great depths (over 100 m) [9, 12, 21-25]. Depression of natural immunity was manifested by a decrease in bactericidal properties of skin and salival lysozyme, lowering of blood complement titers, decreased absorption and digestion capacity of blood neutrophils. Evidently, one should interpret the increase in number of colonies of conditionally pathogenic microorganism in skin impressions of divers after repeated deep dives as the result of impairment of bactericidal properties of the skin [23]. At the same time, leukocytosis, elevation of level of C reactive protein and titers of normal antibodies in blood, which were observed in a number of instances in aquanauts [12, 24], are most probably the consequence of a developed infectious-inflammatory process. Data indicative of presence of neutrophilia and lymphopenia in the blood of divers after numerous dives merit special attention [9, 11]. Since analogous blood changes are also often encountered in the presence of acute stress, there is reason to believe that stress can develop during diving as a result of exposure of man to a number of extreme factors, and it is associated with impairment of immunobiological reactivity of the body. The results of experimental studies, which showed that exposure of mice to a hyperbaric helium and oxygen mixture (8 ata [atm(abs.)], 20°C temperature) leads to elevation of levels of epinephrine, norepinephrine and dopamine in blood [17], indicative of activation of adrenal function and inherent in the initial phase of development of the systemic adaptation syndrome (the authors consider hypothermia to be the cause of stress), are also in favor of this hypothesis. Investigation of immunobiological reactivity of mice exposed to a helium-oxygen or nitrogen-oxygen environment at pressure of 8 and 7 ata, respectively, revealed that there is severe inhibition of interferon production under hyperbaric conditions [18, 26]. Since animal resistance to viral infections is largely related to interferon content of tissues [27], it is logical to assume that expressly impaired production of interferon under hyperbaric conditions causes an increase in mouse sensitivity to influenza virus, which we mentioned above. In addition to inhibition of interferon production by mice in a hyperbaric helium-oxygen atmosphere, there was also a drastic decrease in phagocytic activity of blood neutrophils [17]. Impairment of interferon production and depression of phagocytic function of neutrophils, which are the most important indices of natural immunity, are interpreted as the result of stress developing under hyperbaric conditions. The etiology of stress under hyperbaric conditions remains unclear, and while hypothermia may be considered one of the possible causes of stress in the case of using hyperbaric helium-oxygen environments, the cause of stress could have been both pressure elevation and the specific effect of nitrogen in the experiments where a nitrogen and oxygen environment was used.

Along with the above data indicative of depression of nonspecific immunity under hyperbaric conditions, there are also observations indicative of the opposite effect. Thus, after 10-, 17- and 30-day exposure to a helium and

oxygen environment at pressure of 35 kgf/cm^2, rabbits presented stimulation of phagocytic activity of blood neutrophils and increased complement and blood lysozyme activity [28]. This stimulation of nonspecific immunity appeared after brief depression of defense systems of the body and, we believe, it was related to development of inflammatory lesions to the animals' integument.

To sum up all of the foregoing, it can be stated that there are very few studies dealing with the effects of hyperbaric gas mixtures on immunobiological reactivity of the organism, and the results of these studies are contradictory to some extent. In spite of the contradictory data obtained by different researchers, it can still be considered that exposure of man and animals to hyperbaric conditions in isolated chambers is associated with an increase in morbidity rate and aggravation of infectious and inflammatory processes. The increased incidence of infectious diseases in a hyperbaric environment is apparently due both to depression of nonspecific resistance of the body and the adverse hygienic conditions in pressure chambers (microbial contamination, high or low temperature, high humidity, etc.). There is also reason to believe that impairment of immunity under hyperbaric conditions occurs as a result of development of stress, the etiology of which is not clear, although it is apparent that overcooling of the body in a helium-oxygen environment or when submerging during underwater work could be causes of stress. The question of whether hyperbaric conditions have a direct effect on immunobiological reactivity of the body remains open, and to answer it comprehensive experiments must be conducted.

Hypobarism: There is even more limited and contradictory information concerning the effects of gas environments at low barometric pressure and normal pO_2 (normoxic hypobarism) on immunobiological reactivity. Experimental studies established that 30-day exposure of mice to a normoxic nitrogen and oxygen environment at a pressure of 368 mm Hg does not affect the animals' resistance to Pasteurella pseudotuberculosis and Pasteurella tularensis [29]. Analogous results were obtained from experiments on mice who were infected intraperitoneally with Staphylococcus aureus during exposure to an atmosphere containing 85% oxygen and 10% carbon dioxide at a pressure of 179 mm Hg [30]. Unlike the above-described studies indicative of the fact that normoxic hyperbarism does not affect development and course of bacterial infections, there are also data indicative of considerable retardation in healing of abscesses produced by hypodermic injection of Staphylococcus aureus in mice exposed to a nitrogen-oxygen atmosphere at a pressure of 259 mm Hg [31]. Authors tend to interpret the greater severity of the pathological process and more sluggish course thereof as the result of decreased immunological reactivity of mice under the influence of hypobarism.

The data concerning the influence of normoxic hypobarism on the course of viral infections in mice turned out to be just as contradictory. Thus, exposure of mice to a pressure of 380 mm Hg had no appreciable effect on development of an infectious process induced by intraperitoneal inoculation

of meningovirus, and animla resistance to the virus decreased only in those cases where there were drastic pressure changes during the experiment [32]. At the same time, it was established that long-term exposure of mice to an atmosphere of pure oxygen at a pressure of 0.2 kgf/cm^2 leads to a sharp decrease in mouse resistance to influenza virus, as manifested by a higher incidence of death due to pneumonia among infected animals [33]. The latter finding is quite consistent with data indicative of inhibition of interferon production in mice exposed to an atmosphere of pure oxygen at a pressure of about 160 mm Hg [26].

To sum up the results of studies dealing with the effect of hypobarism on resistance to infection, we must state that, in view of the limited number of works on this subject and contradiction of published data, it would be premature to derive any conclusions.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

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STUDIES OF VENOUS CIRCULATION IN THE CREW OF THE SALYUT-5 ORBITAL STATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 8-12

[Article by V. A. Degtyarev, A. S. Nekhayev, V. S. Bednenko, O. B. Kulikov, Ye. A. Kobzev, V. M. Bol'shov and A. A. Tsvetkov, submitted 13 Jun 77]

[English abstract from source]

Studies of venous circulation were continued in the space crewmembers of the orbital station Salyut-5. New data which demonstrated again that weightlessness induced symptoms specifically associated with blood redistribution and pressure increase in the jugular veins were obtained. It is suggested to further the studies of venous circulation and regional hemodynamics aimed at determining the time and degree of human body adaptation to weightlessness.

[Text] As we know, redistribution of blood in the upper parts of the body is one of the direct results of weightlessness. Data obtained during the flight aboard the Salyut-4 orbital station revealed that, during the first month of weightlessness, cosmonauts present signs of increased filling in the system of the jugular veins [1]. The concomitant objective and subjective changes (puffiness and redness of the face, hyperemia of the sclera, sensation of rush of blood to the head, etc.) are apparently related to the difficulty of venous efflux from the head and neck, and transsudation of liquid in the interstitial spaces.

Similar phenomena varying in degree occurred in virtually all cosmonauts, during both short- and long-term flights, and they were the most marked during the period of acute adaptation [2, 3]. Thus, it may be assumed that, in view of redistribution of liquids in weightlessness, there is development of a specific set of symptoms that resemble somewhat the clinical signs of the "superior vena cav a syndrome" [4]. With this in mind, research on venous circulation in crew members of the Salyut-5 orbital station was continued and supplemented by focusing rheography of the region of the head, liver and diaphragmatic segment of the right lung.

Methods

The studies were conducted at rest and during a functional test involving lower body negative pressure [LBNP]. Using a method described previously [1],

the arteriovenous pulsogram (AVP) was recorded from the region of the vascular bundle of the neck. We studied the dynamics of amplitudes of presystolic (a) and diastolic (d) AVP waves, as well as the ratio of collapses x and y (Figure 1). The wave amplitude was measured from the isoline traversing the point corresponding to maximum collapse x, and that of collapses x and y, from the apex of the systolic wave (c). Duration of phases of contraction of the right heart was estimated from the AVP curves. Pressure in the system of the jugular veins under ground-based conditions was determined by an indirect method based on the effect of transformation of AVP into a sphygmogram of the carotid artery with passive change in body position and in flight, according to rarefaction in the LBNP device and analogous changes in AVP. Pressure in the pulmonary artery was calculated from the nomogram of Burstin [5]. Rheographic studies were conducted using the Levkoy-ZT instrument [6]. To record rheograms of the head, the electrodes were situated in the frontosuboccipital lead, for rheograms of the liver they were placed 2 cm above the edge of the costal arch and parallel to it in the projection of hepatic dulness, on the level of the third intercostal space, along the centralclavicular line and in the region of the right scapula.

Results and Discussion

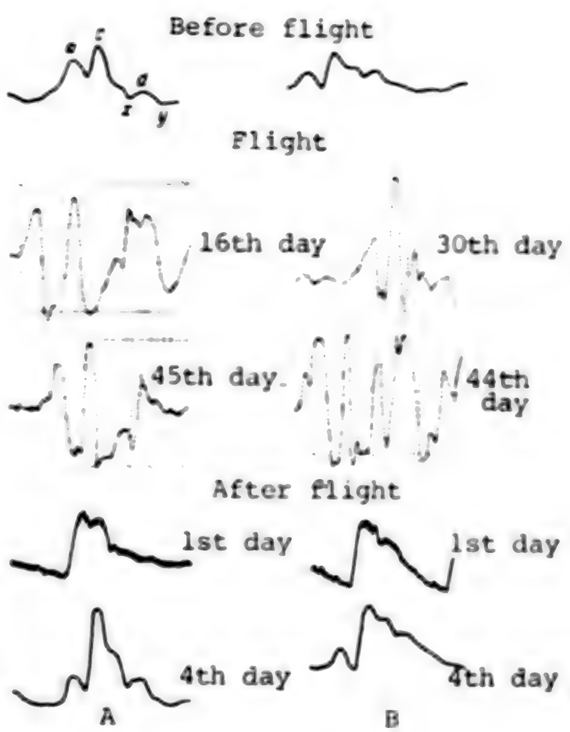

Figure 1.
Dynamics of shape of AVP of B. V. Volynov (A) and V. M. Zholobov (B)

The first studies of venous circulation in B. V. Volynov, V. M. Zholobov and Yu. N. Glazkov were conducted at the end of the 2d week of flight, i.e., during the period of completion of processes of acute adaptation to weightlessness. In V. V. Gorbatko, the AVP was recorded on the 4th day. From the very first day of the flight, the cosmonauts reported signs of venous hypertension. Yu. N. Glazkov, in particular, reported marked edema and ruddiness of the face, while V. M. Zholobov experienced a headache. The relative indices of venous pressure measured in B. V. Volynov and V. M. Zholobov on the 13th-14th day were significantly above preflight levels and remained high on the 30th and 44th-45th flight days (see Table). There was a tendency toward increased amplitude of AVP waves, as was the case in the flight of O. I. Klimuk and V. I. Sevast'yanov [1], indicative of increased filling of jugular veins. Virtually all of the cosmonauts presented an increase in amplitude of diastolic wave and x/y ratio (see Figure 1).

Dynamics of parameters of venous circulation in the crew of Salyut-5 orbital station, at rest in the preflight period, in weightlessness and after the flight

Indices	B. V. Volynov								V. M. Zholobov							
	before flight	in flight					after flight		before flight	in flight						after flight
	days															
	5	14	16	44	45	16	2	4	5	13	30	44	46	47	49	4
HR	59	52	48	60	54	54	60	56	44	45	53	58	70	53	55	52
Aa	70,4	102,5	90,4	81,3	82,2	67,5	36,7	28,5	50,0	94,2	67,9	93,6	80,8	55,5	75,5	33,3
Aα	22,7	65,0	88,0	58,1	53,3	62,1	32,3	25,7	57,1	71,1	—	95,7	68,0	77,7	86,6	—
x/y	0,93	1,48	1,28	1,43	1,79	1,30	0,81	0,86	0,61	0,98	1,36	1,09	0,89	1,41	1,13	—
SA	0,080	0,088	—	0,088	0,079	0,074	0,073	0,082	0,076	0,082	—	0,082	—	0,068	0,068	0,080
T	0,120	0,124	—	0,134	0,127	0,126	0,114	0,104	0,115	0,100	—	0,125	0,115	0,103	0,103	0,115
E	0,325	0,294	0,323	0,312	0,293	0,298	0,306	0,316	0,320	0,303	—	0,274	0,253	0,265	0,301	—
IR	0,068	—	0,088	—	0,090	—	—	0,070	0,0[illegible]	0,088	—	—	—	0,084	—	—
Ppa	15—20	—	30—35	—	35—40	—	—	15—20	15—20	25—30	—	—	—	30—35	—	—
Pjv	4,9	9,8	—	11,2	11,2	—	2,4	2,4	5,1	19,4	—	17,8	—	—	—	5,1

Key: Aa, Aα) amplitude of AVP waves (% of amplitude of wave c)
x/y) ratio of collapse values
HR) heart rate
SA) atrial systole
T, E and IR) intervals of tension, ejection of blood and isometric relaxation, respectively, of right atrium (in s)
Ppa) blood pressure in pulmonary artery (mm Hg)
Pjv) blood pressure in the system of jugular veins (mm Hg)

Such changes could have been due to difficult influx of blood from the venae cavae and right atrium into the ventricle, because of an increase in reserve systolic volume of blood in the right ventricle [7]. They could serve, to some extent, as signs of elevated pressure in the pulmonary circulation [8]. It should be noted that the estimated pressure levels in the pulmonary artery of cosmonauts during the flight period remained somewhat elevated.

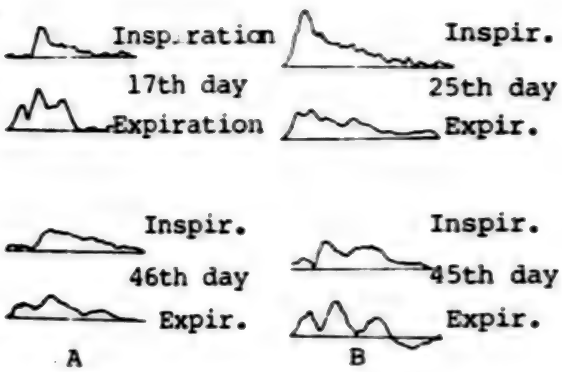

Figure 2.
Changes in shape of rheogram of head region of B. V. Volynov (A) and V. M. Zholobov (B) during flight

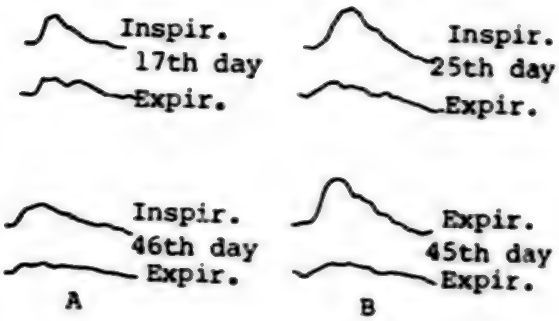

Figure 3.
Change in shape of rheogram of hepatic region and diaphragmatic segment of right lung of B. V. Volynov (A) and V. M. Zholobov (B) during flight

As was expected, the results of rheographic examination were quite interesting (Figures 2 and 3). Thus, on the 17th day, the rheogram of B. V. Volynov, taken in the head region, was characterized by appearance of an additional venous wave and formation of a tall peak in the diastolic segment of the curve. In V. M. Zholobov, the rheogram flattened down on the 25th day; a plateau appeared in the region of the peak of the pulse wave and the diastolic part became slightly elevated. These changes were present during ordinary expiration and disappeared in inspiration. There was some flattening of the curve and drop of incisura to the isoline in B. V. Volynov, on the 46th day. There was a mild venous component in inspiration. The rheographic changes were more marked in V. M. Zholobov. Thus, on the 45th day, a significant venous wave appeared in expiration, the incisura dropped to the isoline, while the diastolic segment of the curve was essentially represented by an additional wave. There was negligible change in shape of the rheogram in inspiration. According to data in the literature [9, 10], such changes could be due to increased filling with blood of the tested region of the head. Evidently, there was inadequate compensation for the

static phenomena in inspiration by the end of the flight, in the case of V. M. Zholobov. He also presented signs indicative of decreased arterial tonus. By the end of the mission, the flight engineer reported recurrence and intensification of headache.

In spite of the fact that there is a substantial change in conditions of venous return in weightlessness, studies of the phase structure of the right heart failed to demonstrate any signs whatsoever indicative of impaired myocardial contractility. Some decrease in duration of right atrial systole and fluctuation of tension interval of the right ventricle did not present distinct dynamics, and most probably they were related to the distinctions of filling of the chambers of the right heart.

While we interpret the persistent pressure elevation in the system of the jugular veins as a sign of incomplete adaptation of the circulatory system to weightlessness, we nevertheless found some signs of compensation of venous return. Thus, on rheograms recorded for the region of the liver and right lung in the 2d month of the mission, there were some typical changes (flattening of the curve, presence of small waves in the diastolic segment) indicative of increased filling of these organs [11], perhaps as a result of deposition of blood in them.

In analyzing the possible causes of long-term venous hypertesnion, which was observed in B. V. Volynov and V. M. Zholobov, we must mention that the crew had a relatively larger routine work load than in other expeditions. In view of the shortage of sleep and asthenization of the body, there could have been impairment of neurocirculatory mechanisms of regulation. The significant elevation of relative indices of venous pressure, as compared to preflight levels, also merits attention. Evidently, such changes cannot be attributed solely to an increase in volume of blood in the system of the superior vena cava. Apparently, one should consider in this case the joint effect of other extracardiac factors, among which venous tonus is important.

On the 1st-2d postflight day for V. M. Zholobov and on the 1st day for B. V. Volynov, examination in horizontal position showed no venous components on the AVP, and the curve had the shape of a carotid artery sphygmogram. At this time, venous pressure was apparently close to zero. The venous components were restored in the commander on the 2d day and flight engineer on the 4th day. The venous pressure of B. V. Volynov was one-half the preflight level, while that of V. M. Zholobov reached the base level. On the day that V. V. Gorbatko and Yu. N. Glazkov landed, there were venous components on the AVP; however, venous pressure of the commander was one-half the preflight level and that of the flight engineer was two-sevenths the preflight level. Restoration of venous components of the AVP and elevation of venous pressure on different postflight days are apparently attributable to individual distinctions of readaptation processes. Tonus of peripheral vessels, fluid-electrolyte balance, muscular activity, etc., play a significant part.

Thus, new objective confirmation was obtained of substantial changes in venous return under weightless conditions. Of the indices of adaptability of the human body to weightlessness obtained in flight, the venous components were the most static [inert]. They also presented the most marked deviations from levels recorded on earth. Since no other equally marked signs were demonstrable, according to which one could determine whether the adaptation process is completed or delayed in relation to flight factors, there is no question that it is imperative to continue these studies.

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FLUID-ELECTROLYTE METABOLISM IN THE CREW OF SALYUT-4

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian
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[Article by G. I. Kozyrevskaya, A. I. Grigor'yev, B. R. Dorokhova, N. M. Vatulya and N. D. Radchenko, submitted 23 Nov 77]

[English abstract from source]

The paper presents the results of studying the fluid-electrolyte metabolism in P. I. Klimuk and V. I. Sevastyanov before and after their 63-day flight aboard the orbital station Salyut-4. Postflight weight losses in P. I. Klimuk and V. I. Sevastyanov were 5.6 and 3.5%, respectively, the losses being attributed to body dehydration. Postflight both cosmonauts showed a trend for an increased renal excretion of potassium, magnesium, and calcium as compared with their food intake. Those were more expressed on the day after the water load application. Possible causes of the changes and the pattern of recovery of fluid-electrolyte metabolism after a prolonged space flight are discussed.

[Text] Substantial changes in fluid-electrolyte metabolism, manifested by impairment of balance of fluid and electrolytes, were demonstrated as a result of clinicophysiological examination of cosmonauts who participated in flights on the national programs of the USSR and United States [1-4]. At the present time, these changes are evaluated as adaptational. However, it is not known whether the demonstrated changes would progress with increase in duration of space flights and how rapidly there would be restoration of hydroionic equilibrium that is customary under earth's gravity.

In this article, we submit the results of a study of restoration of fluid-electrolyte metabolism in crew members of the second expedition of the Salyut-4 orbital station, P. I. Klimuk and V. I. Sevast'yanov, who completed a 63-day flight.

Methods

The study of fluid-electrolyte metabolism in both cosmonauts was conducted against the background of metabolic studies, i.e., in addition to examination of renal excretion of various substances, we also determined the amount thereof taken as part of the food rations. During the period of the

preflight and postflight studies, 24-h urine was collected. Blood was taken from a vein before the flight, as well as on the 2d, 7th and 14th days of the recovery period. Sodium and potassium concentrations were assayed in samples of urine and blood serum using a PFM-1 flame photometer; calcium and magnesium were assayed with an atom-absorption spectrophotometer, and osmotic concentration was determined using cryoscopy with an MT-54M semiconductor microthermistor.

For fuller evaluation of the direction of changes in fluid-electrolyte metabolism, we calculated the indices of renal excretion of fluid and minerals as a percentage of intake thereof [5]. Extrarenal fluid loss was determined by means of standard tables.

Results and Discussion

Renal excretion of fluid and electrolytes, as well as ion content of blood serum, was repeatedly assayed in P. I. Klimuk and V. I. Sevast'yanov prior to the space flight. The obtained, averaged values of the indices studied are listed in Tables 1 and 2. A comparison of levels of diuresis and electrolyte content of urine of both cosmonauts to the findings on subjects examined according to the same program, against the background of metabolic studies, failed to demonstrate any differences. Renal excretion constituted the following mean levels: 53-55% fluid, 68-77% sodium, 68-80% potassium and 18-33% calcium, as compared to the amounts of these substances contained in the diet.

Table 1. Diuresis (mℓ) and electrolyte content of urine (meq/day) for crew members of Salyut-4 station in the preflight period ($M \pm m$)

Crew members	Diuresis	Na	K	Ca	Mg
P. I. Klimuk	900±42	185±14	63±3.4	16±3.2	3.1±0.55
V. I. Sevast'yanov	1280±71	236±21	78±5.0	17±1.3	10.0±0.64

For the first postflight days, P. I. Klimuk and V. I. Sevast'yanov lacked a marked feeling of thirst, as compared to crews of prior missions. Thus, P. I. Klimuk limited his food and fluid intake due to the slight nausea induced by vestibular disorders from the time the spacecraft landed to the following morning (so-called "zero" day), and he consumed only 0.45 ℓ water, with excretion of 0.5 ℓ urine. However, it is extremely difficult to doscise the the positive or negative fluid balance in this case, since both cosmonauts were given a 9 g supplement of table salt on the day they landed, and drank 0.9 ℓ water for partial restoration of extracellular fluid before the spacecraft landed on earth. The fluid excreted by the kidneys,

skin and lungs from morning to the time of landing was not taken into consideration. On the basis of the unchanged body weight on 0 and the 1st day, it may be assumed that fluid excretion was in balance with intake.

Table 2. Electrolyte concentration in blood serum of Salyut-4 crew before and after flight

Crew members	Time of study	Na	K	Ca	Mg	Osmotic concentration, mosmol/ℓ
		meq/ℓ				
P.I. Klimuk	Before flight (M±m)	145±0.9	4.2±0.10	5.6±0.20	1.5±0.9	298±1.2
	After flight:					
	2d day	144	3.7	5.2	1.9	298
	7th day	146	4.3	5.4	1.7	300
V.I. Sevast'yanov	Before flight (M±m)	148±1.0	4.3±0.15	5.0±0.11	1.6±0.06	298±1.8
	After flight:					
	2d day	145	3.9	5.2	1.7	296
	7th day	149	4.4	5.2	1.7	302

It is known that absolute or relative fluid deficiency in the body is a stimulus for the feeling of thirst. A fluid shortage may occur as a result of both cellular and extracellular dehydration. The extracellular phase contains very mobile fluid, circulating blood, the stability of which is maintained by effective and fast-acting mechanisms. Decreased influx of blood into the heart with the transition to earth's gravity is a powerful stimulus for activation of the thirst center and centers that regulate fluid and salt retention. Evidently, the fluid and salt supplement compensated for most of the lost intercellular fluid, excluding one of the stimuli of the sensation of thirst. The remaining fluid deficiency was made up within 3 days due to moisture content of the diet. There was virtually no difference in level of diuresis and fluid intake of P. I. Klimuk, as compared to base levels, starting on the 3d day of the recovery period. By this time, he had regained 2.4 kg (Figure 1).

From the time the sapcecraft landed, on 0 day, V. I. Sevastyanov drank 1.2 ℓ fluid and excreted 0.47 ℓ urine. On subsequent days, fluid intake increased to 3.2 ℓ and, with metabolic fluid, it constituted 3.6 ℓ. This amount of fluid was sufficient to eliminate the remaining weight loss (see Figure 1). The water load test, conducted on the 2d postlanding day, did not alter the dynamics of the 24-h balance. However, marked diuresis developed on the following day, against a background of considerably decreased fluid intake (see Figure 1), which led to a reliable weight drop, from 68.8 to 67.8 kg. This weight persisted to the end of the week, and it reached the background level only on the 8th day of the recovery period. Consequently, regulation of fluid metabolism did not reach normal on the 2d-3d postflight days, and the body could not react adequately to intake of a large amount of fluid at one time.

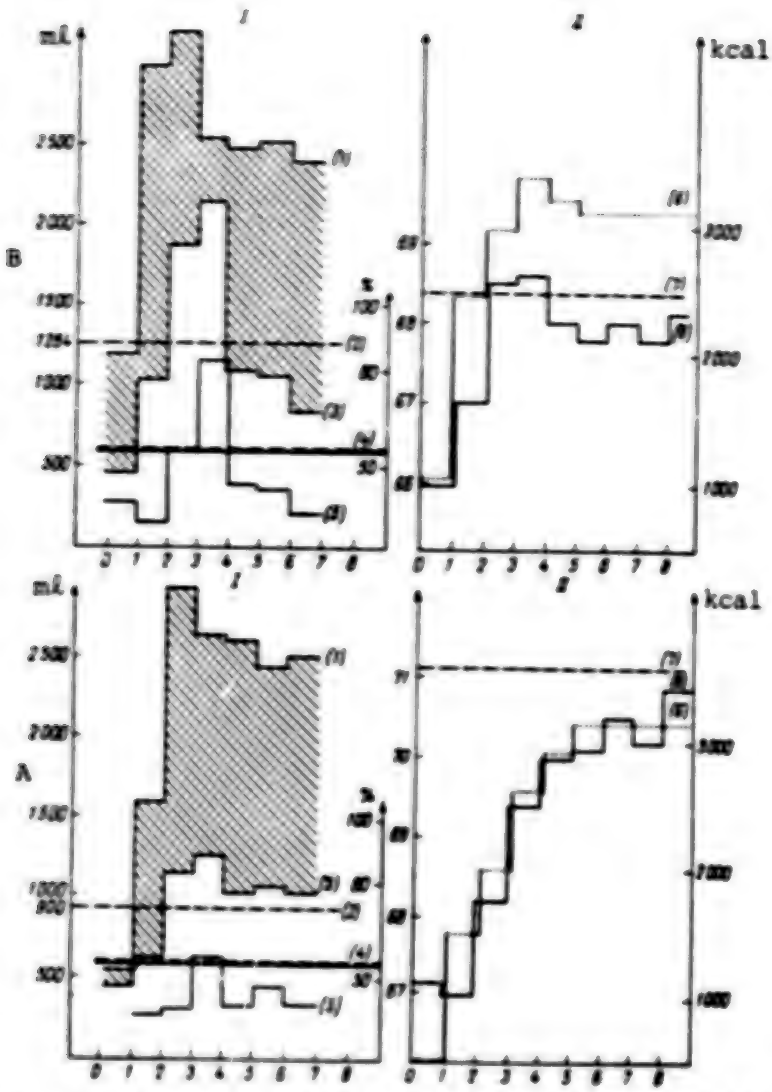

Figure 1. I. Dynamics of fluid intake, diuresis (mℓ/day) and renal excretion (%) for P. I. Klimuk (A) and V. I. Sevast'yanov (B)

II. Dynamics of restoration of body weight (kg) and caloric value of food ration (kcal) for P. I. Klimuk (A) and V. I. Sevast'yanov (B).

X-axis, postflight days; y-axis:

I) fluid intake and diuresis (mℓ) on the left; renal excretion of fluid (%) on the right

II) body weight (kg) on the left; caloric intake, numbers on the right

1) fluid intake after flight
2) diuresis in background period
3) postflight diuresis
4) renal excretion of fluid in background period
5) renal excretion of fluid after flight
6) caloric value of food
7) body weight in background period 8) postflight body weight

There has been repeated discussion in the press of the causes of weight loss during space flights. In the opinion of most researchers [4, 6-9], there may be several: loss of body fluid, prevalence of catabolic processes, inconsistency between caloric value of food and energy expenditure of cosmonauts. Special attention was devoted to the latter factor in flight.

Individual daily balance was comprehensively determined prior to the flight. However, in the course of the flight, there were discrepancies between the planned and actual energy expenditure by the cosmonauts. The fact that V. I. Sevast'yanov consumed his entire food ration during the flight could be one of the reasons for this. P. I. Klimuk had a somewhat poorer appetite, although he expended more energy, since he was more actively involved in exercises. We cannot rule out the possibility that, for expressly this reason, the commander lost more weight than the flight engineer. The weight loss constituted 4 and 2.4 kg, respectively (see Figure 1). Analysis of the dynamics of restoration of body weight in the postflight period revealed that P. I. Klimuk lost about 2.4 kg referable to fluid and about 1.6 kg referable to body tissues. These figures were 1.6 and 0.8 kg, respectively, for V. I. Sevast'yanov. The larger share of fat in weight loss of P. I. Klimuk warrants the belief that there was relatively minor muscular atrophy.

Renal excretion of fluid, as a percentage of fluid intake with food and beverages, was low to about the same extent in both cosmonauts on all days tested, with the exception of the day after the fluid load (see Figure 1). Nevertheless, it should be borne in mind that, while this phenomenon was the result of fluid retention directed toward elimination of negative balance thereof, which developed in weightlessness, on the first few days, fluid excretion on subsequent days could have been low due to increased extralenal loss as a result of increased motor activity and high ambient temperature in the area where the studies were conducted.

Renal excretion of sodium in the postflight period was subject to less change than other electrolytes in P. I. Klimuk and V. I. Sevast'yanov (Table 3 and Figure 2). With the exception of 0 day and the day after the fluid load, the concentration of sodium, daily excretion thereof in urine and percentage of excretion by the kidneys were within the range of individual fluctuations, and they virtually failed to differ from base values (see Figure 2). On the day after the fluid load, against the background of more intensive diuresis, there was a sharp increase in sodium excretion, along with increase in excretion of other electrolytes (see Table 3) and osmotically active substances. Diuresis resembled osmotic diuresis, and most likely it was due to hemodynamic changes.

There have been repeated reports of changes in renal excretion of calcium and magnesium after space flights [2, 3, 10]. There were more marked changes in the crew of the first expedition of Salyut-4 orbital station, and it was particularly marked in P. I. Klimuk and V. I. Sevast'yanov after the 63-day flight. Renal excretion of calcium and magnesium reached a mean of 42-44% of intake thereof with food, which was almost 10% above the maximum

level observed in the preflight study (see Table 3 and Figure 2). This can be evaluated as loss of calcium in the bone system, related to functional inactivity of the skeletomuscular system in weightlessness.

Table 3. Fluid (mℓ) and electrolyte (meq) intake with food (I), daily excretion thereof in urine (II) and ratio of excretion (%) to intake (III) in the postflight period, in crew members of the Salyut-4 station

Crew members	Post-flt. day	Fluid			Na			K			Ca			Mg		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
P.I. Klimuk	1	1600	606	38	0	52	—	60	87	145	0	17.1	—	0	9.2	—
	2	3380	1352	40	267	72	27	94	105	111	46	22.9	50	29	12.7	44
	3	2540	1470	56	230	266	115	91	145	159	41	25.1	61	28	16.1	58
	4	2600	1055	41	256	244	96	97	78	81	47	19.3	41	30	10.5	35
	5	2456	1150	47	244	212	87	86	132	154	40	18.0	45	25	12.4	51
	6	2500	1060	42	255	200	78	78	135	173	41	17.5	43	28	10.3	37
V.I.Sevast'yanov	1	3130	1050	33	244	179	73	86	74	86	40	22.0	55	25	9.4	38
	2	3420	1694	55	200	192	64	95	83	87	47	19.3	41	29	10.4	36
	3	2570	2175	84	261	376	144	91	140	157	41	26.0	62	28	13.4	48
	4	2500	1100	44	286	205	72	98	103	106	47	22.8	49	30	10.0	33
	5	2500	1085	43	250	218	87	76	133	176	40	16.6	42	24	8.2	34
	6	2400	835	35	250	159	64	84	86	104	41	18.8	46	28	10.2	36

The dynamics of potassium excretion in the postflight period differed in crew members of the second expedition aboart Salyut-4. There was a greater increase in concentration of potassium in urine on the very first postflight day in the commander (see Figure 2). On some days, potassium excretion reached 160% (see Table 3). Elimination of potassium did not revert to normal to the end of the observation period. The same phenomenon was first observed in A. A. Gubarev and G. M. Grechko after a 30-day space flight, but the potassium concentration was somewhat low, while increased excretion thereof by the kidneys occurred against the background of more intensive diuresis due to increased fluid intake.

At the present time it is generally recognized that a negative potassium balance during space flights is due to a decrease in cell mass. In this case, it becomes apparent that restoration of impaired potassium balance by means of increased intake thereof with food is impossible. Even with normal regulation of potassium on the cellular level, it is difficult to assimilate until the cell mass is restored adequately to conform with the increased demands of the body.

Nor can we rule out the possibility of increased renal excretion of potassium due to higher amount thereof in the diet (up to 120 meq). Nevertheless, intake of a large amount of potassium with food is justified, since it was one of the causes of rapid normalization of level thereof in blood serum. A decrease in potassium content of blood serum was noted in the crew of the

second expedition aboard the Salyut-4 orbital station after landing (see Table 2), as was the case after the 30-day flight of A. A. Gubarev and G. M. Grechko. However, on the 7th day of the recovery period after the 62-day mission, potassium content of blood serum reached the base levels, whereas after the 30-day flight there was still marked hypokalemia at this time. Evidently, additional intake of potassium, along with other rehabilitation measures, was instrumental in faster restoration of its level in blood serum.

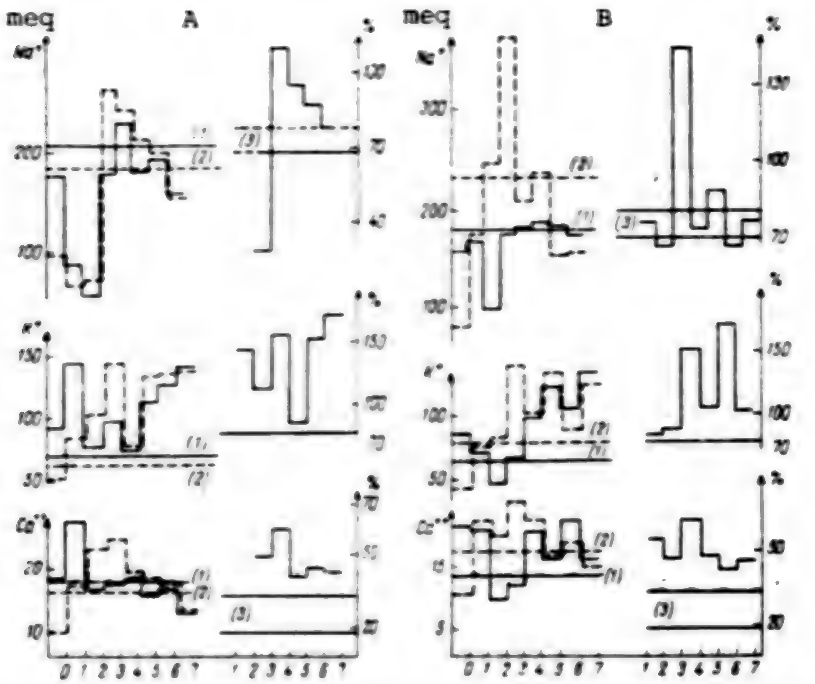

Figure 2. Dynamics of postflight renal excretion of electrolytes in P. I. Klimuk (A) and V. I. Sevast'yanov (B).
X-axis, postflight days; y-axis, electrolyte content (meq) on the left, renal excretion (%) on the right.

1) electrolyte concentration (meq/ℓ)
2) daily excretion (meq/day)
3) range of probable fluctuations, M±m·t

Thus, fluid-electrolyte homeostasis that is consistent with the conditions is formed during longer flights. It is important to mention that there is also retention of functional correlations between all physiological systems of the body. However, one should be very cautious in referring to dynamic equilibrium of lfuid-electrolyte metabolism within the range of the new established functional level of the body. As shown by the data obtained from the third mission of Skylab [11], renal excretion of potassium and calcium increased with increase in duration of the flight. Changes in mineral metabolism, which are a manifestation of impairment of metabolic

processes, may cause substantial changes in osmoregulatory function of the kidneys, by altering transport of fluid, electrolytes and urea in the tubules.

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CONTROL OF VERTICAL POSITION AFTER FLIGHTS ABOARD THE SALYUT-4 ORBITAL STATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 18-22

[Article by V. I. Myasnikov, O. P. Kozerenko, N. M. Rudometkin, V. M. Mikhaylov and V. S. Georgiyevskiy, submitted 14 Mar 77]

[English abstract from source]

[Text] One of the elements of the process of readaptation of a cosmonaut following a space flight is restoration of his ability to maintain an upright position. This does not present any difficulty to a healthy individual, due to the coordinated interaction between functional systems that organize and regulate adaptive behavior [1-3]. At the same time, difficulties are observed in cosmonauts with regard to locomotion and organization of muscular coordination, and retention of an upright position after landing, which is manifested outwardly by dyskinesia, asynergia and other neurological symptoms [4-6]. The stabilography method was used on the crew of the Soyus-4 and Soyuz-5 spacecraft and revealed an increase in amplitude and undulant change in frequency of oscillations of the body's center of gravity [7].

Our objective here was to demonstrate the distinctions of regulation of vertical postion and autonomic reactions to it after prolonged weightlessness, as well as to investigate the process of restoration of the initial level of regulation of the upright position.

Methods

We studied postural function with maintenance of specified vertical position using the stabilographic method [8]. This method enabled us to repeatedly demonstrate changes in position control after flights [7, 9]. Standing with the eyes closed and Romberg's position were used as load tests. Before and after these load tests, tracings were made with the subjects in a natural position, with the arms dropped, in a so-called comfortable ["at ease"] position. The tests lasted 2 min in each position. We recorded pulse rate and arterial pressure by the tachyoscillographic method with the subject lying down, before and during the stabilographic examination. The crew members of Soyuz-17 and Soyuz-18 spacecraft underwent preflight examinations 1.5 months before lift-off. The crew of Soyuz-17 was examined three times after landing: G. M. Grechko was tested after 9 h, on the 2d day and on the 5th day, A. A. Gubarev after 9 h, on 2d and 7th days. The crew of Soyuz-18 was tested on the 2d and 12th days after landing.

Results and Discussion

The preflight examination of crew members of the Salyut-4 orbital station revealed individual distinctions of static adaptation in the above positions. Analysis of frequency of oscillations of the body's common [general?] center of gravity (OTsTT) was concerned mainly with first order waves (up to 0.45 s period), since postflight changes therein were found to be more informative than second order waves (1.0 to 2.5 s period).

Examination of A. A. Gubarev and G. M. Grechko 9 h after landing was conducted only in the "at ease" position, without recording circulatory indices. Holding this position was associated in both cosmonauts with disappearance of individual differences in frequency components of the stabilographic curves and appearance of high-frequency components. Of all shifts of OTsTT, 96% for A. A. Gubarev and 85% for G. M. Grechko were referable to oscillations with a period of 0.15 s. This was associated with changes in maximum amplitude: it increased by 6 mm in the sagittal plane and decreased by 1 mm in the frontal plane in A. A. Gubarev; in G. M. Grechko, it decreased by 10 mm in the sagittal and 7 mm in the frontal plane.

The structure of OTsTT oscillations and nature of postural regulation of circulation differed from preflight levels on the 2d day after landing, in both crews. Although virtually the entire range of frequencies was already present in the structure of oscillations, the most typical finding was retention of high-frequency oscillations with a period of 0.1-0.15 s in all positions, and these oscillations were not inherent in crew members prior to the flight. P. I. Klimuk was the only exception: in one of the preflight tests (with the eyes closed) he presented 72% oscillations with a period of 0.1 s (Figures 1 and 2). The maximum amplitude of OTsTT shifts was less than the base value in A. A. Gubarev and G. M. Grechko; it was close to the base level in P. I. Klimuk and greater in V. I. Sevast'yanov. It must be noted that the differences from preflight levels in frequency and amplitude composition were on the same levels in both crews, in spite of

the fact that A. A. Gubarev and G. M. Grechko had flown on a 30-day mission, while P. I. Klimuk and V. I. Sevast'yanov had spent 63 days in weightlessness.

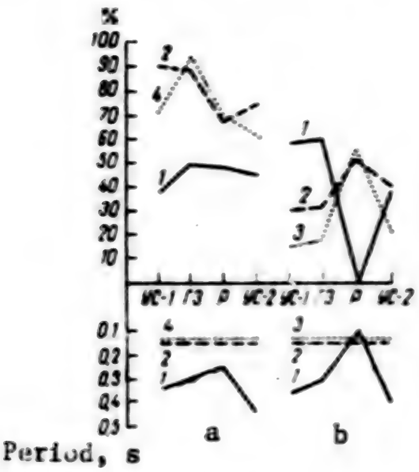

Figure 1.
Changes in high-frequency component of OTsTT oscillations in sagittal plane, in A. A. Gubarev (a) and G. M. Grechko (b)

1) before flight
2) 2d postflight day
3,4) 5th and 7th postflight days

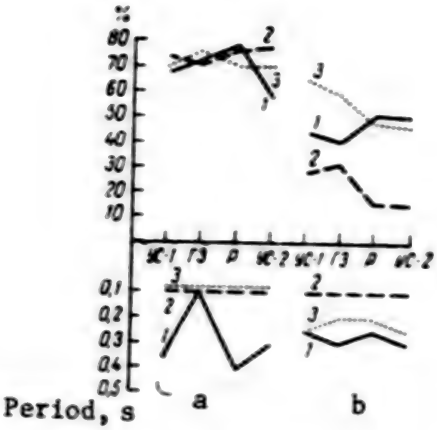

Figure 2.
Changes in high-frequency component of OTsTT oscillations in sagittal plane, in P. I. Klimuk (a) and V. I. Sevast'yanov (b)

1) before flight
2) 2d postflight day
3) 12th postflight day

Y-axis, top: percentage of total oscillations during time spent in specified position; bottom: oscillation period. X-axis:
X-axis: YC) "at ease" P) Romberg position ГЗ) eyes closed

The changes in structure of OTsTT oscillations were associated with changes in circulatory parameters. While standing on the "stabiloplatform" all four cosmonauts presented a faster heart rate, as compared to preflight levels: 5/min faster in A. A. Gubarev, 14/min faster in G. M. Grechko, 29/min faster in P. I. Klimuk and 33/min in V. I. Sevast'yanov. However, it should be noted that the heart rate was also higher just before the test in horizontal position in all cosmonauts, by 11-21/min, as compared to the preflight level. The minimum pulse arterial pressure decreased by 4-11 mm Hg as a result of elevation of diastolic arterial pressure. Mean dynamic arterial pressure rose by 13 and 15 mm Hg in A. A. Gubarev and V. I. Sevast'yanov, respectively. In addition, although the nature of the postural reaction of the cardiovascular system did not change, the degree thereof diminished in A. A. Gubarev, remained the same in G. MW Grechko and increased in both crew members of Soyuz-18. We failed to demonstrate differences in circulatory parameters during load tests, as compared to the "at ease" position.

Testing of G. M. Grechko (5th day), A. A. Gubarev (7th day) and P. I. Klimuk (12th day) revealed that the structure of OTsTT oscillations essentially regained individual features, with regard to both frequency and amplitude, but the high-frequency component of first-order waves was retained in the form of paroxysmal inclusions. The percentage thereof increased when standing with the eyes closed and in Romberg's position. This high-frequency component was no longer demonstrable on the stabilogram of V. I. Sevast'yanov on the 12th day, and all frequency and amplitude indices of upright position were close to preflight values. It should also be noted that the dynamics of recovery of stabilographic indices were essentially consistent with the subjective sensations of the cosmonauts.

As for the data pertaining to circulation, they changed little, as compared to the 2d postflight day. We should mention, however, that there was an increased increment of heart rate in vertical position in G. M. Grechko, to 24/min, although this increment constituted 10-11/min before the flight and on the 2d day after landing.

Monitoring of restoration of preflight physical condition of cosmonauts was based on consideration of the body's capacity for great intensification of functions, stable level of function for the duration of the required work period, as well as resistance to changes in the environment and disruptive factors [10, 11].

The data from the preflight stabilographic studies were used as parameters of optimum level of control of vertical position. Accordingly, appearance of a high-frequency component with a period of 0.1-0.15 s, faster heart rate, elevation of diastolic and, in part, mean dynamic arterial pressure (hyperintensification of function), paroxismal changes in the postural system to function at this frequency (instability of function) and reactions to load tests differing from preflight ones (lack of resistance to disruptive factors) were evaluated as deconditioning indices. The changes in stabilographic parameters are the result of the complex effect of aftereffect of adaptation to weightlessness combined with the process of readaptation to earth's gravity.

Analysis of the obtained data from these positions revealed that there was normalization of control of vertical position from test to test. The time of occurrence of the main readaptation changes differs from the time of reverse development [regression?] of stabilograms of cosmonauts A. G. Nikolayev and V. I. Sevast'yanov after their 18-day flight aboard Soyuz-9. Then, significant changes in stabilographic parameters were noted on the 35th day after landing [10]. All this, as well as the fact that the postflight findings did not reflect differences in duration of orbital flight of crews of Soyuz-17 and Soyuz-18, could be attributed to the effectiveness of preventive measures, which alleviated readaptation. Perhaps, the fact that P. I. Klimuk and V. I. Sevast'yanov, who had participated in the longer flight, already had experienced postflight readaptation to earth's gravity, also played a role.

It may be assumed that worsening of control of upright position is related to inadequate supply of blood to the relevant parts of the brain, as a result of postural hypotension, elements of which had already been found during the first manned space flights and were present in all subsequent flights. Indeed, signs of postural hypotension--increased increment of heart rate and lowering of pulse pressure--were noted in all members of both expeditions aboard the Salyut-4 orbital station after the flight. However, the lack of coinciding changes in heart rate of crew members of the two missions, as well as difference in time of recovery of circulatory parameters and OTsTT oscillations, are in contradiction to this hypothesis.

Thus, the stabilographic studies of the crews of two expeditions aboard the Salyut-4 orbital station enabled us to demonstrate worsening of control of vertical position, which is related to deconditioning of the postural-tonic system and the main readaptation changes that occurred in the 1st week of the postflight period.

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EFFECTS ON LIPID METABOLISM IN MAN OF SOME FACTORS THAT SIMULATE SPACE FLIGHT CONDITIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 22-26

[Article by V. P. Bychkov, A. G. Kasatkina and O. S. Khokhlova, submitted 4 Feb 77]

[English abstract from source]

Studies of the effects of space flight simulation factors on lipid metabolism showed that space diets developed for space flights of different duration (dehydrated foodstuffs alone or in combination with foods preserved by other methods) did not produce noticeable changes in lipid metabolism. Nevertheless, other factors, i. e. hypokinesia, intake of nerobol during hypokinesia, an altered work-rest cycle, an increased carbon monoxide concentration (up to 15 mg/m³) influenced lipid metabolism.

[Text] At the present time, much attention is being given in all countries of the world to changes in lipid metabolism in man, both in the presence of diverse pathology and under the influence of alimentary and nonalimentary factors, particularly when associated with stress reactions. This is attributable, in particular, to the fact that obesity and atherosclerosis are among the most widespread diseases in developed countries [1].

The tense nature of professional activities and unusual working conditions of pilots and cosmonauts compel us to pay close attention to the state of their lipid metabolism. Several authors [2, 3] have found higher cholesterol and β-lipoprotein levels in blood serum of pilots than in individuals in other occupations. Symptoms of coronary atherosclerosis were found in the American astronaut, Erwin, who flew aboard Apollo 15 [4, 5]

No appreciable unidirectional changes in parameters of lipid metabolism were demonstrated in cosmonauts after brief flights aboard Vostok and Voskhod-2 spacecraft [6-9]. In blood samples taken from crew members of Voskhod-1 on the day they landed, cholesterol content constituted 260-290 mg%, versus the usual 120-130 mg% for them, and it dropped to base levels only after 2 weeks [10]. No appreciable differences in cholesterol and lipid phosphorus indices before and after flights were observed in the blood of

10 crew members of Soyuz spacecraft (flights lasting up to 5 days) [11, 12]. After the flight aboard Soyuz-9, a decline of blood cholesterol was found in V. I. Sevast'yanov and an elevation in A. G. Nikolayev [12].

In the three crew members of the Salyut-1 orbital station, mean blood cholesterol content was 217 mg% before the flight, 170 mg% on the 5th day of the flight, 150 mg% on the 15th day and 172 mg% on the 22d day of the flight [13]. In cosmonauts who flew aboard the Apollo spacecraft, there was a tendency toward decline of blood cholesterol level after the flights, as compared to preflight levels, and the American researchers attributed this to a change in diet [14]. During these flights, food intake was not sufficient to mantain an energy balance [14, 15]. The postflight decline of cholesterol level could also have been the result of thyroid hyperfunction, which was found in the crew members of these spacecraft [16].

It is known that lipid metabolism is affected by diet, relationship between caloric value of food and expenditure of energy, level of muscular activity, functional state of the nervous and endocrine systems [17, 18]. There is information to the effect that hyperoxia [19], hypoxia [20] and increased carbon monoxide concentration [20] affect the parameters of lipid metabolism. All these factors could have been involved during space flights.

Since there is very sparse information about changes in lipid metabolism during actual space flights and interpretation thereof is difficult, it is deemed purposeful to investigate the influence on lipid metabolism of different factors simulating space flight conditions.

Until complex systems of food regeneration are developed, the diet of cosmonauts in flight will consist mainly of canned [preserved] foodstuffs, which will be exposed to a set of flight factors during storage, including galactic radiation and solar bursts. All this makes it necessary to make specific selections of foodstuffs and it transforms nutrition into one of the flight factors that affect cosmonauts, including their metabolism.

Weightlessness is one of the main and constant space flight factors to which man is exposed. On earth, some of its effects are simulated by hypokinesia, which could have a considerable influence on lipid metabolism. Thus far, this question has been little-studied, and most investigations were conducted without strict regulation of food intake.

This article deals with analysis of the influence on man's lipid metabolism of food rations used during space flights, as well as of certain other factors simulating space flight conditions: hypokinesia, change in daily cycle of work and rest, increased concentration of carbon monoxide, etc.

Methods

These studies were conducted on 108 healthy men ranging in age from 19 to 45 years (25 series of studies lasting 19 to 421 days). Their food intake

was strictly controlled. The caloric value of rations specially developed for space flights was consistent with the body's expenditure of energy. The subjects consumed freshly prepared foods at the initial and recovery stages. The rations during the experimental and background periods were similar in chemical composition. The subjects were examined by a special medical commission, and they were under constant medical supervision throughout the period of the studies.

The following indices of lipid metabolism were determined in blood serum taken from the subjects' vein in the morning, on a fasting stomach: total lipids, total and esterified cholesterol (with deduction of free cholesterol content and percentage of esterification), phospholipid phosphorus, percentage of α- and β-lipoproteins using methods that have been published previously [21-23].

Results and Discussion

We studied the effects of food rations (combination of dehydrated food and products preserved by other methods) developed for flights lasting up to 1 month [21, 24] on indices of lipid metabolism, both under ordinary living conditions (9 subjects, 30-35 days) and in sealed chambers (19 subjects, 10 series of studies lasting 19 to 35 days). It was established that, under ordinary conditions and in the chambers, with normal work and rest schedule, these diets failed to elicit appreciable changes in indices of lipid metabolism [4, 23]. In the chamber experiments with altered daily work and rest schedule, there was an elevation of cholesterol level (227±14 mg%, versus 172±10 mg% with the usual schedule; $P<0.01$), total lipids (678±31 mg%, versus 608±35 mg%; $P>0.05$) and β-lipoproteins (76.4±1.2 versus 70.3±1.8%; $P<0.02$) on the 10th-17th days [21-23, 25].

We studied the influence of food rations consisting entirely of dehydrated products that were reconstituted before intake under ordinary conditions (6 subjects for 2 months and 6 for 6 months) and in the sealed chambers, with normal daily schedule of work and rest (3 subjects for 29 days, 3 for 30 days and 3 for 1 year). There were no appreciable unidirectional changes in indices of lipid metabolism [23, 26-28].

There were also no changes in indices of lipid metabolism in 20 subjects who received rations of dehydrated products after long-term storage (for 1 and 2 years) and exposure to protons in doses of 12,000 and 24,000 rad, respectively, for 70 days [29, 30].

There were 10 subjects involved in studies with 120-day hypokinesia (bed rest). They received a diet of freshly cooked products containing the required amounts of all essential ingredients in a well-balanced proportion. Along with changes in a number of physiological and biochemical indices [31], the subjects presented significant changes in lipid metabolism. On the 35th day of hypokinesia, there was an increase in blood serum total lipids (810±46, versus 631±47 mg% in the base period; $P<0.02$), cholesterol (218±13,

versus 177±7 mg%; P<0.01) and β-lipoproteins (78.8±1.2, versus 75.7±1.5%; P>0.05). There were no further adverse changes in indices of lipid metabolism thereafter (70th and 105th days of hypokinesia). Administration of the anabolic hormone nerobol to 3 subjects during 120-day hypokinesia enhanced the adverse changes in lipid metabolism [32, 33].

We also studied the indices of lipid metabolism in two series of 49-day investigations (8 and 9 subjects) involving hypokinesia (bed rest, with the head of the bed tilted down by 4°). In the first series of studies, the indices of lipid metabolism in the base period and on the 38th day of hypokinesia were as follows: 710±29 and 731±33 mg%, respectively (P>0.05), total lipids, 188±9 and 172±8 mg% (P>0.05) cholesterol, 75.4±1.3 and 80.8±1.0% β-lipoproteins (P<0.05). By the end of the study, no further changes in lipid metabolism were noted. In the second series of studies, the indices of lipid metabolism in the initial period and on the 48th day of hypokinesia were as follows: 626±33 and 596±20 mg%, respectively (P>0.05) total lipids, 177±11 and 215±9 mg% (P<0.02) cholesterol, 75.4±1.7 and 79.7±1.7 mg% β-lipoproteins (P>0.05). It should be noted that there were considerable individual fluctuations of the subjects' reactions to hypokinesia.

Marked changes in some indices of lipid metabolism were found in 8 subjects (2 series of 30-day studies, with 4 subjects in each) during their stays in airtight chambers with high carbon monoxide content (up to 15 mg/m^3). The subjects were on the same diet as the crew of the Salyut orbital station. In the first series of studies, the indices of lipid metabolism in the base period and on the 22d day of exposure to carbon monoxide were as follows: 587±20 and 1075±73 mg%, respectively (P<0.001) total lipids, 179±10 and 239±17 mg% cholesterol (P<0.05), 65.7±4.6 and 75.6±2.8% (P>0.05) β-lipoproteins. In the second series of studies, these indices of lipid metabolism in the initial period and on the 30th day of exposure to carbon monoxide were as follows: 634±37 and 910±44 mg%, respectively (P<0.002) total lipids, 151±8 and 239±22 mg% (P<0.01) cholesterol, 69.7±3.9 and 76.5±3.1 β-lipoproteins (P>0.05). The subjects presented marked individual fluctuations of β-lipoprotein concentration. There were no appreciable changes in indices of lipid metabolism of 4 subjects who participated in a 90-day study with a concentration of 10 mg/m^3 carbon monoxide in the chamber.

Thus, these studies revealed that the subjects' food rations, which were developed for space flights of different duration (combination of dehydrated and preserved foods, or dehydrated food alone), did not elicit noticeable changes in indices of lipid metabolism. At the same time, such factors as hypokinesia, nerobol against the background of hypokinesia, change in daily schedule of work and rest and high concentration of carbon monoxide in the atmosphere of airtight chambers (to 15 mg/m^3) had a considerable effect on indices of lipid metabolism. Further investigations are need to determine more accurately the influence on lipid metabolism of both individual space flight factors and the set of factors inherent in actual flights.

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ELECTROLYTE COMPOSITION OF RAT BLOOD PLASMA AND SKELETAL MUSCLES AFTER FLIGHT ABOARD THE COSMOS-690 BIOSATELLITE

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[Article by V. P. Nesterov and R. A. Tigranyan, submitted 14 Mar 77]

[English abstract from source]

Measurements of Na^+, K^+, Mg^{2+} and Ca^{2+} concentrations in the functionally different muscles (soleus, plantaris, diaphragm muscles) and plasma of the rats flown for 20.5 days aboard the biosatellite Cosmos-690 did not show any significant changes as compared with the controls. At the same time a decrease of the K^+/Na^+ ratio and a similar shift of Mg^{2+} and Ca^{2+} concentrations in plasma of irradiated rats as compared with these of non-irradiated animals demonstrated that the combined effects of space flight factors and gamma-irradiation influenced the system of ionic homeostasis in the blood. In the animals sacrificed on the R + 1 day the K^+/Na^+ ratio in the soleus muscle changed in favor of Na^+ and in the plantaris muscle in favor of K^+, and remained essentially unchanged in the diaphragm. The comparison of the flight experiments with the ground-based controls showed that ion changes in muscles occurred due to ionizing radiation rather than due to weightlessness.

[Text] As shown by previous studies aboard Cosmos-605, long-term weightlessness induces some changes in selectivity of muscular tissue of animals to ions of alkaline and alkaline-earth metals [1]. This redistribution of ions in tissues could serve as an indicator of functional and biochemical changes, which occur in muscles under the influence of the extreme factors of space flights. What is new in this study is monitored exposure of animals to radiation from an onboard source for the purpose of differentiation between the effects of radiation and gravitational space flight factors.

Methods

We studied skeletal muscles and internal medium of male Wistar albino rats weighing 200-250 g after a flight aboard Cosmos-690. We examined the following groups of animals: PO-1 and PO-2, experimental, sacrificed 1 and 26 days after the flight; SC-1 and SC-2, ground-based synchronous control simulating flight conditions, with the exception of weightlessness, and IC, intact control (vivarium animals). On the 10th day of flight, the animals were

Table 1. Electrolyte content of rat blood plasma, meq/ℓ

Animal group	n	Na^+	K^+	Ca^{2+}	Mg^{2+}	P_{inorg}, mg%	Cl^-	K^+/Na^+	Mg^{2+}/Ca^{2+}	$\Sigma[Me]$
PO-1	5	140,0±6,2	5,3±0,7	4,7±0,7	2,3±0,7	5,8±1,0	116,8±2,0	0,0378	0,489	152,3
SC-1	5	138,2±10,3	5,2±0,6	4,9±1,0	1,6±0,5	6,5±0,3	108,6±4,7	0,0376	0,326	149,9
PO-2	5	144,0±10,3	3,9±0,8	6,2±0,9	1,5±0,4	7,3±1,4	113,2±7,9	0,0271	0,242	155,6
SC-2	5	148,0±9,2	5,0±1,2	4,6±0,9	2,1±0,3	6,4±0,8	118,8±5,1	0,0338	0,456	159,7
IC	8	141,8±8,5	4,8±1,4	5,2±0,7	1,9±0,3	6,6±0,6	117,0±8,9	0,0338	0,365	153,7

Note: Here and in Table 2, n is the number of animals examined. The concentration of $P_{inorganic}$ is given in mg%.

exposed to γ-radiation aboard the biosatellite to a cumulative dose of 200 rad in 24 h. Control animals were also irradiated.

We examined the following skeletal muscles: soleus, which is referable to the group of slow phasic muscles and perform essentially a tonic postural function in the body, plantaris, which is a rapid, mainly white muscle that effects chiefly rapid motor reactions, and the phrenic muscle, which occupies an intermediate position.

Skeletal muscles were treated in the same way as in our preceding study [1]. Concentration of Na^+, K^+, Mg^{2+} and Ca^{2+} in mu-cle tissue and blood plasma was determined by the method of atomic absorption spectrophotometry [2]; inorganic phosphate and chlorine ions of blood plasma were assayed by the method of automatic analysis [3, 4]. Tissue concentrations of ions were expressed in milliequivalents per kg wet tissue and ion content of the medium, in milliequivalents per liter blood plasma.

Results and Discussion

No reliable changes in endogenous ion composition were demonstrable in blood plasma of animals after the flight, as compared to the control (Table 1); nor was there a decline of K^+/Na^+ ratio in PO-2 animals, as compared to PO-1, which is the opposite of the tendency observed in animals involved in the experiment aboard Cosmos-605 biosatellite [1]. In spite of the fact that, with this number of experiments, these changes have little statistical reliability, analogous redistribution of concentrations of two other cations, Mg^{2+} and Ca^{2+}, in the blood plasma of PO-2 animals, as compared to PO-1, indicates that the combination in this experiment of space flight factors and onboard γ-radiation apparently affected the system of ion homeostasis of blood. The relative redistribution of concentrations of ions of alkaline and alkaline-earth metals was not associated with significant change in overall cation supply of plasma ($\Sigma[Me]$; see Table 1).

The concentration of two other important components, inorganic phosphate and chlorine ions, also failed to differ in the animal groups studied (see Table 1).

At the present time it is considered as an established fact that there is functional determination of distribution of ions of alkaline metals in intact muscles [5, 6]. The distribution of Na^+ and K^+ in muscles of flight and control animals conformed with this pattern: in all groups, the K^+/Na^+ ratio increase in the following order: soleus, phrenic and plantar muscles, i.e., with increase in muscular capacity to perform rapid phasic contractions and loss of tonic properties. The changes in tissular concentrations in muscles could be related to both differences in volumes of intracellular fluid (VIF) and difference in ion selectivity of fibers. One day after the animals landed, the K^+/Na^+ ratio changed in favor of Na^+ in the soleus muscle, in favor of K^+ in the plantar muscle, with no change in the phrenic muscle (Table 2).

The reliable dehydration of the plantar muscle of PO-1 animals, as compared to both types of controls, warrants the assumption that an increase in K^+/Na^+ reflects a relative decrease in tissular VIF. Estimates indicate, however, that this alone cannot explain the relative change in tissular ion composition. A 22 m /kg decrease in VIF of the plantar muscle in PO-1 animals, as compared to SC-1, would lead to more than 3 meq/kg decrease in concentration of Na^+ and no more than 2.5 meq/kg increase in concentration of K^+. On the other hand, a 2.1 meq/kg decrease in concentration of Na^+ in flight animals due to decrease in volume of interstitial fluid would lead to only a 1.6 meq/kg increase in concentration of K^+, which is also different from the mean experimental data. The obtained data indicate that, along with changes in tissular concentrations of ions due to a decrease in VIF, there may also be relative intracellular redistribution of ions of alkaline metals in favor of K^+ in the plantar muscle of PO-1 animals. This means that functional exclusion of the rapid phasic muscle, which apparently occurred during long-term weightlessness, may lead to storing of additional free energy by fibers, in the form of a higher transmembrane ion gradient.

The tonic postural function of the soleus under normal gravity conditions is effected by means of continuous impulsation from slow motoneurons. Mechanical relaxation of the muscle, which apparently occurs in weightlessness, is perceived and transmitted in theform of proprioceptive afferent impulsation to these motoneurons, inducing the corresponding changes in efferent innervation of the muscle. Biochemical changes, an indication of which is increase in K^+/Na^+ in tissue, develop in a muscle deprived of normal neural influence, incluidng trophic [7]. Redistribution of ions, decrease in weight and certain other changes demonstrable in the soleus of animals that had participated in a long-term space flight resemble the signs of development of denervation atrophy of skeletal muscles after denervation thereof [8, 9].

The phrenic muscle must implement the necessary respiratory activity of animals, regardless of exogenous conditions; for this reason, the change in gravitation does not lead to impairment of the established stationary functional and biochemical status of this muscle, and it does not cause a change in its cation balance.

Table 2. H_2O content (m ℓ/kg wet mass), Na^+, K^+, Ca^{2+} and Mg^{2+} (meq/kg wet mass) in rat skeletal muscles

Muscle	Animal group	n	H_2O	Na^+	K^+	Ca^{2+}	Mg^{2+}	K^+/Na^+	Mg^{2+}/Ca^{2+}	Σ [Me]
Soleus	PO-1	5	761±1	34,8±2,2	85,5±2,7	3,5±0,2	20,1±1,1	2,46	5,74	143,9
	SC-1	8	777±5	31,6±2,1	93,5±2,5	3,7±0,2	17,9±1,0	2,96	4,84	146,7
	PO-2	5	767±7	32,2±2,7	89,6±2,7	4,0±0,4	20,0±1,2	2,78	5,00	145,8
	SC-2	5	769±6	31,1±2,3	92,2±3,1	3,7±0,4	18,1±0,8	2,96	4,90	145,1
	IC	18	765±3	31,6±1,1	93,4±2,7	3,1±0,2	18,6±0,7	2,95	6,00	146,7
Phrenic	PO-1	10	725±5	30,2±1,9	96,7±2,5	3,5±0,3	21,7±1,1	3,20	6,20	152,1
	SC-1	8	742±1	31,5±2,0	95,9±2,2	4,1±0,3	20,3±1,3	3,04	4,95	151,8
	PO-2	6	739±5	31,4±2,0	92,7±2,4	4,1±0,4	22,1±1,3	2,95	5,39	150,3
	SC-2	5	740±5	31,1±2,1	96,2±2,7	3,8±0,4	19,0±1,7	3,09	5,00	150,1
	IC	22	730±3	29,7±1,8	97,8±2,1	3,6±0,2	20,0±0,9	3,29	5,55	151,1
	PO-1	10	744,4	19,1±0,9	115,5±2,0	2,9±0,3	23,3±1,4	6,05	8,04	160,8
			$P<0,01$							
Plantar	SC-1	8	766±5	21,2±1,7	111,6±2,7	3,5±0,3	23,3±1,7	5,27	6,66	159,6
	PO-2	6	761±6	20,1±1,7	103,5±3,1	4,0±0,3	22,7±1,9	5,15	5,68	150,3
	SC-2	5	760,6	20,7±2,0	107,1±4,2	3,9±0,4	22,4±2,0	5,18	5,74	154,1
	IC	22	759±3	20,2±1,2	108,5±2,1	3,7±0,2	21,8±0,8	5,37	5,90	154,2

The postflight period was characterized by return of altered K^+/Na^+ content in the plantar and soleus muscles to the levels inherent in intact animals (see Table 2).

Analysis of Mg^{2+} and Ca^{2+} content of the muscles studied failed to reveal reliable changes in concentrations of these ions. Thus, the parameters studied are resistant enough to ionizing radiation (lack of differences between animals in the synchronous experiment and intact control). A comparison of the results of flight experiments to ground-based controls revealed that ion changes in muscles are the consequence of the influence of altered gravity, rather than ionizing radiation.

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INTENSITY OF DNA SYNTHESIS IN ANIMAL ORGANS AFTER FLIGHT ABOARD THE COSMOS-782 BIOSATELLITE

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[Article by F. T. Guseynov, I. A. Yegorov, G. S. Komolova and R. A. Tigranyan, submitted 31 Dec 76]

[English abstract from source]

With respect to H^3-thymidine incorporation the rate of DNA synthesis in the liver, spleen and thymus of rats was determined in flight and synchronous rats. Six hours postflight the rate of H^3-thymidine incorporation into the liver of flight rats did not differ from the normal (vivarium controls) and was 50% higher than in the synchronous rats. In the spleen and thymus of flight animals this parameter was 60 and 33% below the norm. Similar but less pronounced changes in the spleen were found in the synchronous rats. Twenty-five days postflight the rate of DNA synthesis in lymph organs recovered completely and tended to increase, whereas in the liver it remained significantly below the norm.

[Text] A study of rat organs after a 22-day flight aboard Cosmos-605 biosatellite revealed that the DNA content of the liver and spleen [1] and intrinsic viscosity of DNA from the spleen [2] do not change appreciably 1 and 26 days after the flight, with the exception of some tendency toward decrease in DNA content of the spleen 1 day after the flight. Other authors have also reported the lack of changes in thymocyte DNA content [3], although they did find reliable, but reversible cytomorphological changes in lymphoid tissue and the blood system. Analogous reversible changes in the spleen of mice [4], as well as liver of mice and guinea pigs, were demonstrated after short-term flights in previous experiments [5]. There are also data concerning a reliable increase in incidence of chromosomal aberrations in mouse bone marrow [4] and in a culture of peripheral blood leukocytes of cosmonauts [6] following flights of varying duration.

In this work, we submit the results of analysis of intensity of DNA synthesis in the liver, spleen and thymus of albino rats after a 20-day flight aboard the Cosmos-782 biosatellite.

Methods

The experiment aboard Cosmos-782 was conducted with two ground-based controls: Control-1 (vivarium) with special feed and Control-2 (synchronous experiment) in a mockup of the biosatellite under flight conditions.

The animals were given intraperitoneal injections of 5-methyl-^{3}H-thymidine (11.8 Ci/mmole) at the rate of 1 μCi/g weight 4 h before they were sacrificed. After decapitation, pieces of extracted organs were thoroughly washed in cold 0.25% saccharose solution, rapidly frozen and stored in Dewar flasks with dry ice.

DNA was extracted with hot 0.5 N perchloric acid after hydrolysis of RNA with alkali and removal of acid-soluble products from batches of air-dried defatted tissue powder [7]. Radioactivity of extracts was determined using a toluene scintillation mixture with triton X-100 [8, 9] (SL-30 liquid scintillation counter, Intertechnique, France); DNA concentration was also assayed (spectrophotometrically). We calculated specific radioactivity of DNA (SR DNA, counts/min·μg). The data were submitted to statistical processing according to Student.

Results and Discussion

The Table lists the results of our experiments. The animals' weight constituted 250-270 g 6 h after landing and 300-330 g after 25 days. The SR DNA of organs of all animals (including controls) examined 25 days after the experiments was found to be high, as compared to the early stage. For this reason, it would be purposeful to analyze the results of all experiments on the basis only of the results obtained on the corresponding control (vivarium) animals. After 6 h, the SR of liver DNA of flight anumals was virtually normal (vivarium control), whereas in the liver of animals in the synchronous experiment this index was about 50% higher than normal ($P<0.05$).

These data are consistent with the results of assaying DNA in the rat liver 1 day after the flight aboard the Cosmos-605 biosatellite and in the synchronous experiment [1]. For this reason, it may be considered that an increase in biosynthesis of DNA under the influence of the specific conditions under which the animals were kept, among which hypokinesia was in a prominent place, is one of the causes of high DNA content in the liver of animals in the synchronous experiment (Cosmos-605). The lack of analogous changes in the liver of flight animals could be attributed to the influence of weightlessness, which apparently prevents intensification of DNA synthesis and increase in content thereof.

It is also apparent, from the data listed in the Table, that SR of spleen DNA in flight animals was 2-2.5 times lower 6 h after the experiments than in control animals of both variants (Control-1 and Control-2). The differences are statistically reliable, and they are indicative of significant

depression of uptake of radioactive precursor in splenic DNA at the early postflight stages. Minor depression (by 15%) was also observed in the spleen of animals in the synchronous experiment, as compared to the vivarium control.

Incorporation of ^{3}H-thymidine in DNA (SR DNA, counts/min·μg) of rat organs following 20-day space flight aboard the Cosmos-782 biosatellite ($M \pm m$)

Variant of experiment	Liver		Spleen		Thymus	
	after 6 h	after 25 days	after 6 h	after 25 days	after 6 h	after 25 days
1. Control-1 (vivarium)	13.1* ± 0.04	28.5 ± 3.06	58.1 ± 12.41	109.6 ± 14.22	18.2 ± 1.49	22.5 ± 2.29
2. Control-2 (synchronous)	20.0 ± 2.07 $P_{1,2} < 0.05$	21.2 ± 3.51	49.5 ± 3.56	116.2 ± 40.52	12.7 ± 0.76	27.5 ± 2.61
3. Flight	14.4 ± 1.34	17.3 ± 1.03 $P_{1,3} < 0.05$	22.9 ± 2.55 $P_{1,3} < 0.05$; $P_{2,3} < 0.01$	114.8 ± 13.09	12.5 ± 0.72 $P_{1,3}$ = $P_{1,2} < 0.05$	27.9 ± 2.1

*The results are arithmetic means of SR DNA of corresponding organs of 5-6 animals; in turn, the SR DNA of each organ is the arithmetic mean of 3-4 readings.

On the whole, the findings in the thymus are analogous to those in the spleen. However, the absolute values of SR DNA in the thymus are considerably lower (of the same order as in the liver) and more reliable (by about 33%), but not as marked as in the spleen of flight animals. Depression of ^{3}H-thymidine uptake in DNA is observed in the thymus not only of flight animals, but those in the synchronous experiment.

Thus, if we assume that there are no appreciable changes in levels of endogenous precursors (in this case, thymidine), on the basis of the obtained data it may be concluded that an appreciable decrease in intensity of DNA synthesis is observed 6 h after landing in the spleen and thymus, in contrast to the liver. Changes in the same direction were also present in organs of animals in the synchronous experiment; however, there was less marked depression of DNA synthesis in the spleen (but not in the thymus). It may be assumed that the set of factors associated with space flights and lacking in the synchronous experiment (in particular, weightlessness) intensifies the depressing effect of specific upkeep conditions on DNA synthesis in the spleen. In the thymus, however, apparently because of its greater sensitivity to diverse extreme factors, depression is equally marked, and one cannot demonstrate differences between animals in the flight and synchronous experiments on the basis of this index.

If we consider that hypokinesia is the main factor involved in the synchronous experiment, we could conclude that this factor has a depressing effect on DNA synthesis in the spleen and, particularly, in the thymus at the early stages after exposure to it.

With reference to causes of depressed DNA synthesis in the rat spleen and thymus at the early postflight stages and at the end of the synchronous experiment, we should mention, first of all, the role of steroid hormones (glucocorticoids), excretion of which, as we know, increases in the presence of stress. The elevated glucocorticoid level has a lympholytic effect [10, 11], due to synthesis of DNA, RNA and proteins in lymphoid tissue [12-14 and others].

SR DNA of the liver of vivarium animals (Control-1) is higher after 25 days. It was 25 and 39% higher than the SR DNA of the liver of animals in the synchronous (Control-2) and flight experiments, respectively. The reverse was observed in the spleen and thymus.

It is easy to see that the direction of changes from normal in all organs of animals in the flight and synchronous experiments was, on the whole, the opposite of what occurred at the early stages (6 h after the experiments). At the later stages, metabolic processes are intensified in lymphoid tissue and inhibited in the liver, probably as a result of redistribution of energy and plastic resources, as a compensatory reaction. Increased uptake of labeled precursors in spleen DNA [13] and increased mitotic activity in the thymus [14] are observed after adrenalectomy.

The level of incorporation of ^{3}H-thymidine on the whole, in all organs and variants (including controls), 25 days after the experiments was higher than at the preceding time. We cannot state that this is related to age-related changes in DNA synthesis. It is known that the levels and intensity of biosynthesis of nucleic acids do not increase in many organs with age, on the contrary, they decrease [15-17].

Evidently, the decrease in dilution of the isotope after injection is the most probable cause of increased uptake of labeled precursor in DNA of animal organs examined 25 days after the experiments. This could be related to two factors: 1) depletion with age of endogenous stock of precursors, in particular thymidine; 2) lack of correlation between internal organ weight increment and increase in total body weight with age. Since the radioactive precursor is given according to the animals' total weight, in the case of lack of change or lag in weight gain of different organs, as related to total weight gain, there would be less dilution of the tracer in this organ, and the amount of isotope per gram organ weight increases which, in turn, would lead to increased incorporation of ^{3}H-thymidine in DNA.

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EFFECT OF BRIEF HEAD-DOWN POSITION ON PARAMETERS OF CARBOHYDRATE METABOLISM AND BETA LIPOPROTEIN CONTENT OF BLOOD

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[Article by A. A. Seid-Guseynov, V. Ye. Katkov, V. V. Chestukhin, L. I. Shefter, N. S. Zakharova and Ya. A. Sokolov, submitted 24 May 77]

[English abstract from source]

Before and after 5-day bed rest in the head-down position (at an angle of −4.5°) the healthy male test subjects were exposed to selective catheterization with blood samples withdrawn from different compartments of the cardiovascular system. The content of glucose, insulin, lactic acid and β-lipoproteins was measured. After bed rest the systemic circulation — mixed arterial and venous blood — showed a trend for a decrease of carbohydrate metabolism and an increase of the content of β-lipoproteins. Transcapillary metabolism in different organs, first of all, in the brain and liver altered significantly. The liver began to release glucose and ceased to utilize lactic acid whereas the brain increased substantially its release of β-lipoproteins. The data obtained were analyzed using a model of carbohydrate metabolism to control and artificial pancreas.

[Text] Investigation of adynamic states is of great practical importance, not only in connection with implementation of programs of manned space flights, but to clinical practice, where such states occur whenever a patient is compelled to remain in bed for a long period of treatment. At the present time it is already well known that, even in healthy individuals, adynamic states lead to changes in metabolic activity of tissues and various forms of metabolism, including that of carbohydrates [1-5]. Moreover, as shown by experiments on animals, there is a definite organ- and tissue-specificity of metabolic changes under such conditions. However, we were unable to find any information in the literature concerning distinctions thereof in healthy man.

One should also devote much attention to organic redistribution of glucose and insulin in diabetic patients, due to the need to devise regulation systems for machines of the "artificial pancreas" type [8-10]. However, such investigations as a whole, as well as on healthy individuals, are general in nature thus far, and they do not take into consideration the specific nature of changes in different organs.

Our objective here was to investigate the effect of brief antiorthostatic hypokinesia [head-down position] (ANOG) on intraorganic redistribution of glucose, insuline, lactic acid and β-lipoproteins in healthy subjects.

Methods

Selective catheterization was performed, taking blood samples from different parts of the cardiovascular system, on healthy male volunteers before and after 5 days of bed rest in antiorthostatic position, with the head end of the bed tilted at an angle of -4.5°.

The tests were made on a fasting stomach or after a light breakfast. Catheterization was performed under roentgenotelemonitor control; we also recorded an EKG, pressure and oxygenation of blood. One catheter was passed, through a puncture in the ulnar vein, to vessels of various organs, while another remained in the radial artery.

Glucose content was assayed by the glucose oxidase method using a glucose analyzer [11]; insulin was assayed by the radioimmune method using double antibodies [12], lactic acid was determined by the method of Barker and Sammerson [13], and β-lipoproteins by the turbidimetric method [14].

The results were processed on a computer, and the t criterion was used for statistical analysis.

Results and Discussion

After 5 days of ANOG, against the background of about the same changes in systemic circulation (mixed venous and arterial blood), there were substantial differences in dynamics of parameters for blood of organic veins (see Table).

It should be noted that some differences in transcapillary metabolism were already demonstrated at the initial stage. Thus, there was excessive glucose uptake by the brain and heart, and this appeared against the background of mobilization of carbohydrate reservoirs of muscles and kidneys. With reference to the heart, liver and kidneys, there was excessive uptake of lactic acid; there was a tendency toward assimilation of β-lipoproteins in the kidneys and skeletal muscles, whereas the opposite changes in this parameter were inherent in the brain (Figure 1).

Following ANOG, there was some decrease in concentration of glucose, insulin and lactic acid in systemic circulation, whereas β-lipoprotein content, on the contrary, presented a tendency toward increasing. Against such a background, there was appreciabl[illegible]e in transcapillary organic metabolism, and this was the most typica[illegible]e liver and brain. Thus, the liver began to "discharge" glucose into the systemic circulation ($P<0.05$) and stopped assimilating lactic acid from incoming arterial blood ($P<0.05$), whereas there was a sharp increase in "discharge" of β-lipoproteins by the brain ($P<0.05$, see Figure 1).

Effect of ANOG (bottom row of figures) on indices (M±m) of carbohydrate metabolism and β-lipoprotein content of blood samples taken from different parts of the cardiovascular system

Part of cardiovascular system	Glucose, mg%	Insulin, μunits/mℓ	Lactic acid, mg%	β-lipoproteins, units	n
Radial artery	93.3±4.3	11.5±0.8	10.7±1.0	0.49±0.05	12
	83.7±2.6	10.1±0.4	7.2±1.7	0.54±0.01	7
Brain	80.3±5.4	11.4±0.6	10.2±0.8	0.51±0.05	9
	70.8±3.5	10.7±0.3	7.2±1.5	0.63±0.1	6
Heart	76.0±2.6	11.0±1.0	7.0±0.6	0.49±0.01	4
	69.5±5.0	12.0±2.0	5.5±1.5	0.44±0.02	2
Liver	93.6±4.0	11.0±0.3	7.9±0.9	0.48±0.05	12
	89.2±1.2	10.0±0.4	7.7±1.6	0.55±0.1	7
Kidney	95.6±5.2	11.0±1.0	8.6±1.0	0.45±0.5	10
	81.3±2.3	10.0±0.4	7.3±1.7	0.53±0.1	7
Muscles of lower limbs	94.0±5.0	10.4±0.3	10.0±1.0	0.44±0.05	10
	80.6±1.6	10.1±0.8	7.4±1.5	0.48±0.09	7
Right ventricle of heart (mixed venous blood)	93.5±4.0	11.6±0.9	10.6±1.0	0.46±0.06	12
	85.6±2.0	10.1±0.2	7.3±1.3	0.53±0.08	7

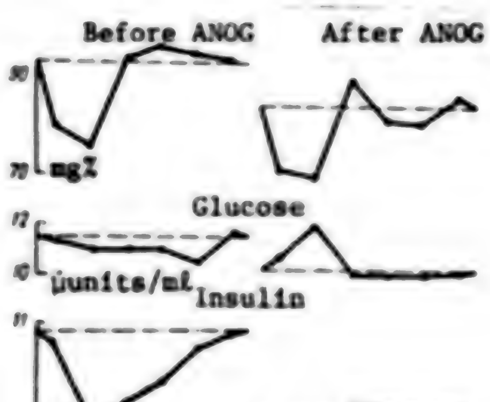

Figure 1.
Effect of ANOG on indices of carbohydrate metabolism and lipoprotein content of arterial blood (dash line) and blood flowing from different organs (for lungs, mixed venous blood)

We decided to use a model of carbohydrate metabolism, which we developed, to analyze the results obtained; it can be used not only to control an artificial pancreas, but to study changes therein in healthy man [15]. In our opinion, this model can also be used to offer a partial interpretation for some of the organic changes in parameters of carbohydrate metabolism under simulated weightlessness conditions.

The model, a flowchart of which is illustrated in Figure 2, is, of course, connected to the circulatory system. Several assumptions were made in designing it: the brain, heart, muscles, kidneys and liver were classified as the main peripheral consumer units of systemic circulation, and the lungs served as the main and sole consumer unit for pulmonary circulation. Under natural conditions, the section that includes the pancreas, intestine and spleen, with subsequent efflux of blood into the liver, occupies a special place in the circulatory

system. Input of insulin in the organism is, of course, related to the pancreas and that of glucose, to the intestine. The liver is the main and primary consumer of glucose and insulin. Under the conditions of our study, this section of the model is considered generalized, i.e., according to arterial input and venous hepatic output. In designing the placement of different organs, it was borne in mind that each would perform two functions: actual tissular metabolism and participation in regulation of basal metabolism for insulin and glucose. The mediated influence of neuroreflex regulation, as well as elements of humoral regulation, including endocrine factors, were considered according to variability of parameters of the described organs, and the influence of the circulatory system, according to distinctions of transport of both controlled and controlling elements and signals.

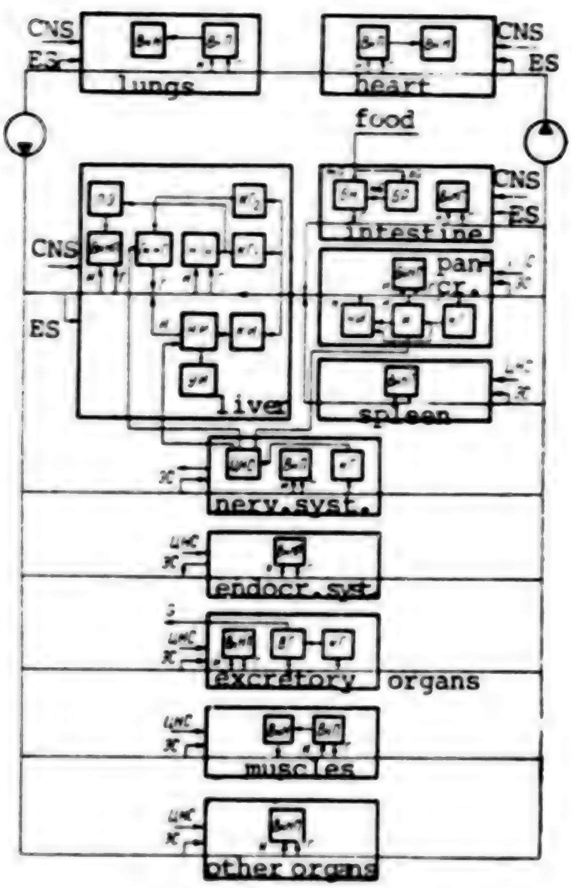

Figure 2.
Flowchart of carbohydrate metabolism

ВиН) internal accumulator
ВиП) internal consumer
ЭС) ES, endocrine system
ПЭ) threshold element
УИ) insulin user
ВнНП) internal accumulator & consumer
ЦНС) CNS, central nervous system
Г) glucose, G
И) insulin, I
КГ) glucose level comparator, CG
НИ) insulin accumulator, IA
КИ) insulin comparator, IC
ВГ) excretion unit, EU
БН) buffer accumulator, BA
БР) splitting unit, SU
Гн) glycogen, Gn
НГн) glycogen accumulator, GnA

In our model, the intestine is a food receiver, in which secretion of glucose into blood takes place via two routes: monosaccharides through a buffer accumulator (BA) and polysaccharides, through a splitting unit (SU). The rate of input of monosaccharides into blood is a nonlinear exponential function of amount thereof in the BA. The rate of input of splitting products

in the BA is also an exponential function of amount of polysaccharides at the output of SU, but the index of the exponential function of SU also includes the rate of the splitting reaction, which reflects the low operating speed of the second channel for input of monosaccharides in blood. In our opinion, this is a simplified model of the carbohydrate-active section of the intestine. Let us recall that we collected blood samples on a fasting stomach, before and after ANOG; for this reason, local tissue metabolism in this part of the intestine apparently played a more important role in this study.

Tissue metabolism proper is represented by the unit of internal consumption and accumulation, which reflects cellular uptake and accumulation of carbohydrates. The rate of uptake by this organ depends on the specifics of the cells proper, size of organ, as well as amount of substance accumulated in cells. The correlation between amount of glucose assimilated and insulin content is 'etermined by the distinctions of each organ and may be considered constant within each organ.

In the first approximation, the model of the pancreas contains a source of secretion of insulin (I), intermediate insulin accumulator (IA) and comparator of glucose level (CG) in incoming blood.

The source of insulin secretion may be considered a source with limited secretion rate and mixed characteristics, indicative of lack of insulin secretion with glucose content below the threshold level. The insulin accumulator is a buffer tank that provides for pulsed delivery of a large amount of insulin to compensate for pulsed access of glucose while ingesting food. The function of the accumulator is of a relaxation nature, and the relaxation period may be considered constant, while the rate of insulin secretion during relaxation depends on concentration of glucose in blood, rate of change therein and amount of stored insulin. Apparently the change in glucose tolerance, which is observed in healthy subjects at the later stages of restricted movement [2], can be attributed to this distinction.

Tissular metabolism proper is analogous to metabolism in the intestine with accuracy to the parameters that determine the distinctive features of cells of a given organ.

The model of the spleen is represented only by tissular metabolism of the organ.

The liver is the most complex model, since it occupies a special place in regulation of carbohydrate metabolism, and this was manifested just as distinctly in simulated weightlessness.

In view of the energy-related role of glucose, the liver can be viewed as a secondary source of energy in the body. For this reason, the homeostatic regulatory mechanism of the liver includes a glucose accumulator (in the form of glycogen) and insulin accumulator. The secondary source of liver glucose consists of a comparator of glucose level in incoming blood (CG_1 and CG_2), glycogen accumulator (GnA) and converter of glycogen into glucose

($Gn \rightarrow G$). When insulin is present in blood, the rate of accumulation of glucose depends on its concentration in blood, volume of accumulated glycogen and it is exponential, the shift characteristic, i.e., accumulation of glucose, is referable primarily to the case when its level in blood is high enough (signal from CG_1). With decline of blood glucose level, the signal from comparator CG_2 triggers the converter of glycogen to glucose ($Gn \rightarrow G$), for which reason it passes into blood, and this is what apparently occurred under the influence of ANOG (see Figure 1).

According to our hypothesis, the mechanism of accumulation and utilization of insulin consists of an insulin comparator (IC), accumulator (IA) and utilizer (IU). There is accumulation of insulin when a certain threshold is exceeded (IC), when the insulin content is greater than the amount required for assimilation of glucose by all organs. With saturation of the accumulator, there is clearance and utilization of insulin. The rate of accumulation of insulin depends on its concentration in blood and amount accumulated in an organ.

In our model, the kidneys are represented by a comparator of glucose level (CG) and excretory units (EU). When the glucose concentration exceeds the permissible range, the comparator issues the signal for excretion thereof.

The other organs do not have an appreciable influence on regulation of carbohydrate metabolism, and they can be represented by elements of tissular metabolism proper, with the exception of muscles, from which accumulated glucose may partially return into blood.

Finally, the nervous system unit includes a comparator of glucose level (CG), while we can arbitrarily disregard accumulation function in the nervous system. In this regard, we are impressed by the fact that, in spite of decline of glucose level in the systemic circulation, delivery thereof to the brain remained "splendid," as before [16]. In other words, immobilization combined with gravitational redistribution of body fluids in general and in the skull in particular had no appreciable influence on the process of glucose utilization by the brain.

In conclusion, it should be noted that the results of this study will be used to develop systems for control of an artificial pancreas and further refinement of models of carbohydrate metabolism of healthy subjects, as related to different conditions of vital functions, including weightlessness.

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INFLUENCE OF PRESSURE CHAMBER CONDITIONS ON ADRENOCORTICAL FUNCTION IN MAN (ACCORDING TO RESULTS OF ASSAYING BLOOD PLASMA 11-HYDROXYCORTICOSTEROIDS)

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 39-42

[Article by S. Kalandarov, V. P. Bychkov and A. V. Sergiyenko, submitted 20 Jan 77]

[English abstract from source]

The effect of a changed atmosphere, hypoxia, hypercapnia, their combinations and different motor activities on the adrenocortical function was studied in 36 test subjects kept in an 8 m^3 altitude chamber. Human adaptation to the environmental changes developed with an active involvement of the adrenal cortex. The level and direction of the changes depended on both the force of the influences and on the initial state of the test subjects.

[Text] The body's adaptability depends significantly on the functional state of the adrenal cortex [1-3], which undergoes certain changes in an altered gas environment. It must be stressed that there are few works dealing with the state of the adrenal cortex in the presence of an oxygen shortage, and such studies were usually conducted for brief periods of time. The results submitted in the literature on this score are contradictory. Thus, some authors [4] observed an increase in adrenocortical function in the presence of hypoxia, while others [5], on the contrary, reported a decrease in activity. Thorn et al. [6] failed to demonstrate changes in adrenocortical function while breathing a hypoxic gas mixture (pO_2 105 mm Hg) for 20-30 min.

There has not been sufficient investigation of function of the adrenal cortex in the presence of hypercapnia, as well as under the combined effect of hypoxia and hypercapnia. It is known that the factor of time spent in an artificial atmosphere is of independent biological significance [7].

There is also an extreme shortage of data on the effect on adrenocortical function of a combination of altered gas environment, hypokinesia and measured physical load.

Our objective here was to study the long-term effect of an altered gas environment (hypoxia, hypercapnia, as well as a combination thereof) and different exercise regimen on adrenocortical function.

Methods

The studies were pursued in an 8 m^3 pressure chamber at normal barometric pressure and with lowering thereof to 405 mm Hg. A total of 36 subjects ranging in age from 22 to 40 years participated in 18 studies (2 people in each, 4 series).

In series I (each study lasting 10 days), adrenicortical function was studied in the presence of hypoxia (studies 1-3), hypercapnia (study No 5) and combination of hypoxia and hypercapnia (study 4). In series II (lasting 14 days), we tested the influence of the following factors on adrenocortical function: normoxic environment combined with simulated malfunction of life support system (LSS) against the background of the usual regimen of physical activity (study 6); hypoxic-hypercapnic environment combined with LSS malfunction against the background of usual physical activity (study 7); hypoxic-hypercapnic environment combined with simulated LSS malfunction against the background of hypokinesia (study 8).

Malfunction of the LSS was simulated by briefly stopping delivery of oxygen into the chamber and removal of carbon dioxide from it.

In series III, we tested the influence of the following factors on adrenocortical function: normoxic environment against the background of hypokinesia (study 9); periodically [cyclic] changing (every 5 days) O_2 and CO_2 levels within the ranges of 105-125 and 1-12 mm Hg, respectively, with ordinary physical activity (study 10); combination of cyclic change in O_2 and CO_2 content against the background of hypokinesia (11th study).

In series IV, we tested the infuence of the following factors on adrenocortical function: normoxic environment against the background of hypokinesia (12th study); periodically changing (3 times a day) O_2 and CO_2 content within the ranges of 105-125 and 1-12 mm Hg, respectively, under hypokinetic conditions (studies 14 and 15); combination of periodically changing O_2 and CO_2 content, hypokinesia and measured physical load (studies 13, 16, 17 and 18).

Each study in the third and fourth series lasted 30 days.

Assay of 11-hydroxicorticosteroids (11-HCC) in blood plasma is the most adequate method of studying adrenocortical function [1, 8]. We assayed 11-HCC of blood plasma by the fluorimetric method [8].

Throughout the studies, the subjects were given a diet that was developed for the crew of the Salyut station. It consisted mainly of canned goods, with a 3-day menu plan for taking 4 meals a day. The mean caloric value of the diet constituted 2913 kcal per day. It contained 147 g protein, 113 g fat, 307 g carbohydrates, 0.8 g calcium, 1.9 g phosphorus, 3.2 g potassium, 5.4 g sodium and 0.3 g magnesium (according to analytical data).

The diet was well-balanced with regard to amounts of the main nutrients, and it contained a high vitamin content, which was given in the form of Undevit lozenges (2 per subject).

Results and Discussion

A minor decline of 11-HCC level of blood plasma was observed on the 2d day of exposure to moderate hypoxia (pO_2 125 mm Hg, study 1). Thereafter (on the 6th day), the amount of 11-HCC reverted to base levels (Table 1).

Table 1. 11-HCC content of blood plasma of subjects exposed to a hypoxic-hypercapnic environment (μg%)

Study No	BG*	Day of exposure		After-ffect effect period
		2	6	
1	27.5	25.1	28.3	31.8
2	27.5	33.1	26.5	23.5
3	24.8	24.1	19.1	28.6
4	18.7	21.8	21.3	19.8
5	21.3	19.3	26.2	26.2

*Background, here and in rest of tables.

The 11-HCC content of plasma increased only on the 2d day in subjects exposed to more marked hypoxia (pO_2 105 mm Hg, study 2). At other times, 11-HCC content was normal. In analogous study 3, conducted after 25-day preadaptation in the mountains (3200 m altitude), there was no appreciable change in 11-HCC concentration on the 2d day. On the 6th day of exposure, 11-HCC level was 23% lower than the base level, whereas after the test it was, on the contrary, 15% higher.

Exposure of subjects to a hypoxic-hypercapnic gas environment (pO_2 125 mm Hg; pCO_2 12 mm Hg) combined with a 2-h decompression test induced elevation of blood plasma 11-HCC level (study 4). In the cases where normal atmospheric pressure and P_{O_2} were maintained in the pressure chamber (study 5), with high CO_2 content (P_{CO_2} 12 mm Hg), there was a decline of blood plasma 11-HCC level on the 2d day and 23% elevation on the 6th day of the study.

We observed elevation of 11-HCC level in plasma when the subjects were exposed to an atmosphere with normal O_2 and CO_2 content in the pressure chamber, as well as with simulated LSS malfunction. After repeating (at the end of the test) the simulated LSS malfunction, we could not demonstrate this effect (Table 2, study 6). We observed a decrease in 11-HCC concentration at the start of the study (5th day) when LSS malfunction was simulated after long-term exposure to a hypxoxic-hypercapnic environment (study 7). Thereafter, plasma 11-HCC content was above background levels. The combination of a hypoxic-hypercapnic environment and hypokinesia (study 8) caused elevation of 11-HCC Level on the 7th day and drop on the 12th day.

Table 2. 11-HCC content of blood plasma in subjects exposed to a hypoxic-hypercapnic environment, as well as hypokinesia combined with simulated LSS malfunction (μg%)

Study No	BG	Day of exposure				After-effect period
		5	7	10	12	
6	22.3	26.8	22.4	22.9	21.0	24.3
7	25.0	17.3	27.4	29.3	30.8	24.2
8	26.4	—	30.1	—	21.5	21.7

Table 3. 11-HCC content of blood plasma of subjects exposed to periodically changing (every 5 days) O_2 and CO_2 levels (μg%)

Study No	BG	Cycle of exposure						After-effect period
		1	2	3	4	5	6	
9	27.0	33.2	22.2	21.1	28.3	38.8	44.4	29.4
10	25.6	29.1	20.1	29.8	15.9	21.6	20.3	22.2
11	27.0	36.1	38.8	31.9	36.1	26.1	31.2	30.1

There was an increase in blood plasma 11-HCC concentration when the subjects "ascended to an altitude" of 7500 m (without supplying oxygen) after prior exposure for 1 month to hypokinesia and normal gas composition of the environment (Table 3, study 9).

Lowering the pO_2 in study No 10 with periodic fluctuation of the main parameters of the gas environment in the atmosphere of the pressure chamber induced an increase in blood plasma 11-HCC content. In the cases where hypoxia was combined with hypercapnia (2d and 4th cycles), the concentration of 11-HCC was lowered. The 11-HCC level was high throughout the study of subjects exposed to an altered gas environment and hypokinesia (study 11).

We see from the submitted data (Table 4) that there was a 14-43% decline of blood plasma 11-HCC level in subjects exposed to a normal atmosphere and hypokinesia (study 12). The combination of a normal atmosphere and hypokinesia, with measured physical load (study 13) had a stimulating effect (elevation of plasma 11-HCC Level throughout the study). Decline of 11-HCC level of blood plasma was observed on the 5th and 23d days of the study in the case of an active, dynamic atmosphere (pO_2 105 and pCO_2 12 mm Hg from 0700 to 1500 hours; pO_2 115 and pCO_2 5 mm Hg from 1500 to 2300 hours; pO_2 125 and pCO_2 1 mm Hg from 2300 to 0700 hours) and hypokinesia (study 14).

There was an increase in concentration of 11-HCC on the 5th and 23d days of the study in the cases where an active dynamic atmosphere (pO_2 125 and pCO_2 1 mm Hg from 0700 to 1500 hours; pO_2 115 and pCO_2 5 mm Hg from 1500 to 2300

hours; pO_2 105 and pCO_2 12 mm Hg from 2300 to 0700 hours) was combined with hypokinesia (study 15). There was a decline of 11-HCC evel on the 12th and 18th days of the study (studies 16-18) under the combined effect of an active dynamic atmosphere (analogous to study 15), hypokinesia and measured physical exercise.

Table 4. 11-HCC content of blood plasma of subjects exposed to an environment with periodically changing (in the course of a day) concentrations of O_2 and CO_2 (μg%)

Study No	BG	Day of exposure				After-effect period
		5	12	18	23	
12	14.5	14.0	12.5	—	8.3	11.0
13	10.5	16.3	14.8	17.1	15.5	13.2
14	14.8	10.1	13.1	12.4	7.7	12.4
15	12.9	14.4	12.0	—	17.3	10.1
16	20.3	18.5	15.8	—	13.7	12.5
17	16.7	19.6	12.5	10.7	14.2	16.2
18	14.2	15.3	12.6	11.6	16.0	21.5

The data obtained in these studies indicate that the adrenal cortex is actively involved in the body's adaptation to the altered habitat in a pressure chamber. This is indicated by changes in functional state of this organ.

The degree and direction of changes were related both to the strength of the factors and initial condition of the subjects.

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ENERGY EXPENDITURES OF MAN DURING LONG EXPOSURE TO A PERIODICALLY CHANGING ATMOSPHERE

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[Article by N. A. Agadzhanyan, V. M. Baranov, M. A. Vytchikova, G. A. Davydov and Yu. A. Spasskiy, submitted 24 Feb 77]

[English abstract from source]

The paper presents the results of studying man's gas exchange and energy expenditures as related to the composition of a cyclically changing environment of an altitude chamber. The experiments were carried out on a 24-hour basis. The paper gives the environmental parameters that physiologically were most adequate as the training factor. The respiratory reactions suggest that the enclosed environment used is suitable to prevent hypokinesia effects.

[Text] One of the most important problems of space flights is physiological substantiation of principles involved in forming an artificial atmosphere in manned cabins of spacecraft.

As we know, when man spends a long time in small pressure chambers, i.e., when his physical activity is restricted, there is a decrease in mental and physical fitness, resistance to accelerations and acute shortage of oxygen [1-6]. Adaptation to hypoxia induces a number of physiological changes in the human body, which are qualitatively the opposite of reactions that occur in the presence of hypokinesia and weightlessness [7-11]. Moreover, the studies of a number of authors revealed that hypoxia induces physiological changes in the body that are similar to those that appear with physical training [12-13].

The changes in the same direction, which are observed in the case of oxygen deficiency and physical training, warrant the belief that it would be desirable to make broader use of moderate hypoxia as a means of preventing hypokinetic disorders, particularly in those cases where it is impossible to exercise.

In this work, we submit the results of our studies of exchange of gases and energy expenditure as related to composition of periodically [in cycles] changing artificial atmosphere in a pressure chamber in the course of a 24-h investigation.

Methods

Seven studies were conducted with the participation of 14 essentially healthy men of about the same age and weight, in an 8 m^3 pressure chamber with normoxic and hypoxic environments.

A dynamic atmosphere, with three changes in partial gas pressures in the course of the day, was used in five studies. The characteristics of test conditions are listed in Table 1.

Table 1. Conditions under which investigations were conducted

Study No	Motor activity	Total press. mm Hg	Partial pressure, mm Hg					
			O_2 (0700 to 1400 hours)	CO_2 (0700 to 1500 hours)	O_2 (1500 to 2300 hours)	CO_2 (1500 to 2300 hours)	O_2 (2300 to 0700 hours)	CO_2 (2300 to 0700 hours)
1	Hypokinesia	760	159	0	159	0	159	0
2	Hypokinesia + exercise	405	159	0	159	0	159	0
3	Hypokinesia	405	105	10	115	5	125	0
4	Hypokinesia	405	125	0	115	5	105	10
5-7	Hypokinesia + exercise	405	125	0	115	5	105	10

In all of the studies, the subjects were submitted to hypokinesia: bed rest with permission to get up only for physiological tests and the set of exercises scheduled for studies 2, 5, 6 and 7; the subjects exercised in the morning and evening (40 min at a time). The intensity of exercise constituted a mean of 875 kg-m/min.

Studies of gas exchange and energy expenditure were conducted by the method of Douglas at relative rest, with the subject reclining in bed, 3 times a day (at 0700, 1400 and 2200 hours, i.e., at the end of each of the three cycles of circadian change in parameters of the atmosphere of the pressure chamber), as well as during exercise on a bicycle ergometer (study 7).

The subjects remained in the dynamic atmosphere for 24 h. In addition, in order to obtain background data and study the aftereffect period, the subjects spent 6 days in the pressure chamber in a normoxic environment. In all, they spent 30 days in the chamber.

Results and Discussion

Oxygen uptake in the course of the day constituted a mean of 240 mℓ/min in a normoxic gas environment (studies 1 and 2). It was somewhat lower in the morning (200-225 mℓ/min) than in the daytime and evening (240-260 mℓ/min). Analysis of levels of oxygen uptake and pulmonary ventilation revealed that an average of 31-32 mℓ oxygen/min (coefficient of oxygen uptake) was utilized in the course of a day per liter air entering the respiratory tract with the body at relative rest; this coefficient was highest in the morning and daytime, and lowest at night. In study 3, with partial oxygen pressure of 125 mm Hg at night, 29 mℓ oxygen (STPD) was absorbed per liter rarefied air. In the second half of the day, at lower partial oxygen pressure (115 mm Hg) 28 mℓ/min oxygen was absorbed and at the time of maximum activity (morning) there was the least efficient uptake of oxygen from air (25 mℓ/min), although ventilation was at a maximum.

Table 2. Energy expended by subjects when exercising on bicycle ergometer (kcal/min)

Time of study	Subjects			
	D.		N.	
	background	load	back grd.	load
Before exposure	1.52	5.38 (№ 1) 7.12 (№ 2)	1.55	5.16 (№ 1) 5.65 (№ 2)
During "	1.48	4.58 (№ 1) 6.30 (№ 2)	1.83	4.92 (№ 1) 5.88 (№ 2)
After "	1.91	5.72 (№ 1) 8.88 (№ 2)	1.67	5.72 (№ 1) 6.18 (№ 2)

Note: Test ["load"] number is given in parentheses.

In studies Nos 5-7, with a dynamic gas environment, there was the least efficient oxygen utilization at night and in the evening hours (26 m /min), while 30 m oxygen was utilized per liter air that passed through the lungs in the first half of the day.

Elimination of carbon dioxide through the respiratory tract corresponded to oxygen uptake levels. We failed to demonstrate a definite pattern in the changes in value of the respiratory coefficient.

Thus, in studies 5-7 with periodically changing atmosphere, the coefficient of oxygen uptake was at a maximum in the daytime, and this may be considered one of the signs of effectiveness of the air environment used.

As noted above, in study No 7 we also examined the energy expended by the subjects when exercising on a bicycle ergometer. These studies were made once a week during exposure to the dynamic atmosphere. Energy expenditure was determined in a state of relative rest, before exercising on the bicycle ergometer and during exercise in a stable state with loads of 550 kg-m/min

(load No 1) and 700 kg-m/min (load No 2). The results of these studies are listed in Table 2. The data submitted in Table 2 indicate that there were similar changes in energy expended by subject D. during exposure to the hypoxic environment, with both load No 1 and No 2. During the exposure period, the level of expenditure of energy decreased, as compared to the levels preceding exposure, then increased again. In subject N., we observed the same pattern with load No 1, whereas with load No 2 there was an increase in energy expended during the exposure period; true, energy expended at relative rest was also higher.

Analysis of the results obtained shows that changes in energy metabolism in the subjects occurred against the background of relative hypokinesia. Hypokinesia per se, which was related to being in a small chamber, lowered energy metabolism, but as a rule there was a greater increment of energy expenditure for a specific exercise, as compared to the state of relative rest, particularly with increase in fatigability [14]. In this regard, it is interesting to analyze the increase in energy expended by the subjects while exercising on the bicyle ergometer, as compared to the state of relative rest (relative difference in expended energy).

The resul's submitted in Table 3 indicate that there is a decrease in relative difference between energy expended by both subjects during exposure to the dynamic atmosphere.

Table 3. Relative difference in energy expended, %

Subject	Load No 1			Load No 2		
	before exposure	during exposure	after exposure	before exposure	during exposure	after exposure
D.	254	213	199	368	325	364
N.	233	169	242	264	221	270

From the standpoint of the well-known principle of minimization of energy expenditure, the decrease in level thereof can be interpreted as improved efficiency [fitness] of the subjects ($P<0.05$ with load No 1 and $P>0.05$ with load No 2). Thus, N. P. Yeremenko established [15] that great mobilization of all physiological mechanisms, which provide for high efficiency, is observed in conditioned athletes when they are "working." One of the manifestations of mobilization of compensatory and adaptive reactions of the body is the decrease in oxygen uptake during stable exercise, which makes it possible to largely compensate for oxygen want during exercise and increases the capacity to perform exercise for a longer time. A. A. Artynyuk [16] also found that, in highly conditioned athletes, cyclic

exercise of near-threshold intensity is performed with less increase in pulmonary ventilation and oxygen uptake, which is indicative of a higher efficiency. The author believes that conditiong develops by means of an increase in efficiency [fitness] during adaptation to hypoxemia.

Previous studies are indicative of a decrease in expenditure of energy during a many-day stay in a small pressure chamber with the usual atmosphere [1, 7, 14].

The finding in study No 7 may serve as additional proof of the beneficial effect of a dynamic gas environment, which is periodically altered in the course of a day, on efficiency of a man who spends a long time in a small chamber under hypokinetic conditions.

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DISTINCTIONS OF INFLUENCE OF THE RETICULAR FORMATION OF THE MIDBRAIN ON THE HEART AND RESPIRATION WITH EXPOSURE TO CENTRIPETAL ACCELERATIONS

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[Article by L. D. Klimovskaya, submitted 24 Feb 77]

[English abstract from source]

Experiments were carried out on white rats and rabbits exposed to transverse accelerations of 6–10 g for 5 min. Before, during and after centrifugation the reticular formation of the midbrain underwent high-frequency electric stimulation. During centrifugation the inhibitory effects of the reticular formation on the cardiorespiratory rhythm decreased, whereas stimulatory effects either remained unchanged or increased.

[Text] Centripetal accelerations induce phasic changes in spontaneous bioelectrical activity of brain structures [1-5]. As a rule, the electrographic changes at the early stages of exposure are indicative of involvement of the reticular activating system of the brain stem, which apparently reacts to the drastic intensification of afferent influx of impulses into the central nervous system. We previously demonstrated that, in rats submitted to 8-fold transverse acceleration, one observes a rather distinct correlation between intensity of electrographic signs of the awakening reaction (appearance of regular θ-rhythm on the electrocerebellogram) and nature of change in rate of respiration and cardiac contractions [6]. According to existing views, the mesencephalic reticular formation is an important element of central mechanisms of regulation of autonomic functions [7]. This work deals with analysis of its influence on the functional state of the cardiovascular and respiratory systems during exposure to centripetal accelerations.

Methods

This study was conducted on 10 waking rabbits and 70 rabbits under superficial anesthesia (40 mg/kg nembutal or 70 mg/kg chloralose intraperitoneally). Bipolar electrodes of nichrome wire (0.1 mm in diameter) in glass insulation, with interpole distance of 0.3-0.5 mm, were implanted in the reticular formation of the mesencephalong according to the approrpiate coordinates. The location

of the electrodes was checked post mortem on histological sections. Square-wave pulses (0.5 ms) from an electronic stimulater with an insulating attachment at the output were used to stimulate the brain. Stimulation time constituted 30 s and frequency, 100/s. The voltage of stimulating current was selected on an individual basis for each animal, with determination of threshold level. The animals were exposed to 6-10 G transverse (back--chest) accelerations on a centrifuge, with a rotation radius of 4.2 m. Time of exposure to a specified level of accelerations was 5 min. During the experiment, we recorded the respiratory excursions, EKG in the second standard lead and additionally, in the tests on rabbits, we recorded spontaneous bioelectrical activity of the mesencephalic reticular formation (lead from a region symmetrical to the one stimulated) on an 8-channel encephalograph with automatic band analyzer. The reticular formation of the midbrain was submitted to high-frequency stimulation before rotation, in the 2d min of exposure to accelerations of the specified level, then 1, 10 and 20 min after stopping the centrifuge. In control experiments, it was shown that no habituation develops to the mode of stimulations we used.

Results and Discussion

At the present time, a rather complete idea has been formed about the changes in function of the cardiovascular and respiratory systems induced by accelerations, the nature of compensatory and adaptive processes, and participation of the autonomic nervous system in them [8, 9 and others]. Figure 1 illustrates a typical reaction of a rabbit to 10-fold transverse accelerations. As can be seen in Figure 1, there was a drastic increase in amplitude and frequency of respiratory excursions, and in heart rate. There was a significant change in nature of bioelectrical activity of the mesencephalic reticular formation. A "stress rhythm" appeared on the electrogram; according to the results of automatic analysis this was associated with considerable decrease in energy of frequencies in the Δ-range (2-4 Hz) and increase in energy of frequencies in the Θ-range (4-8 Hz), which became dominant. Against the background of these changes, there were usually substantial changes in the animals' reactions to stimulation of the mesencephalic reticular formation. Significant decrease or even complete disappearance of reactions, manifested by slowing of heart and respiration rates, was the most noticeable effect of accelerations. This phenomenon is illustrated in Figure 2. Before rotation, stimulation of the regicular formation induced bradycardia and cessation of respiratory excursions in rats. The cardiac and respiratory reactions to electric stimulation of the same intensity were markedly attenuated with exposure to 8 G accelerations. The stimulation effects were restored, though not entirely, 1 min after stopping the centrifuge. When stimulation of the reticular formation induced bradycardia and faster respiration, only the cardiac component of the reaction was significantly diminished during rotation, while the respiratory one usually was retained (Figure 3A). Interestingly enough, accelerations sometimes transformed inhibitory reticular influences into excitatory ones. In the case illustrated in Figure 3B, prior to rotation the rat reacted to stimulation of the reticular formation by a drop in frequency of respiratory

excursions and cardiac contractions; during 10-fold exposure to accelerations it began to react to the same stimulation only by faster respiration. Ten minutes after stopping the centrifuge, the reaction to stimulation of the reticular formation regained the customary form for this animal, but bradycardia was more marked than before rotation.

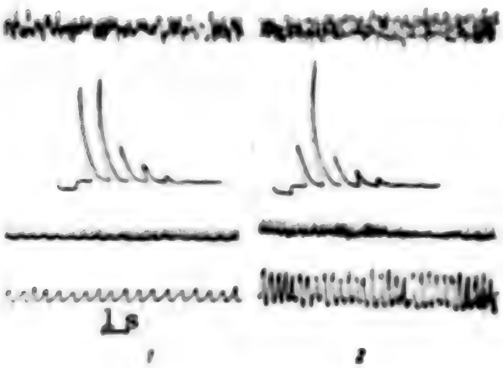

Figure 1.
Rabbit's reaction to accelerations

1) before rotation
2) 2d min of accelerations, 10G

Curves (top to bottom):
electrogram of mesencephalic reticular formation, readings of automatic analyzer for 5 frequency bands [for Δ = (2-4 Hz), Θ = (4-8 Hz), α = (8-13 Hz), β = 1 = (13-20 Hz) and β = 2 = (20-30 Hz)], EKG and pneumogram

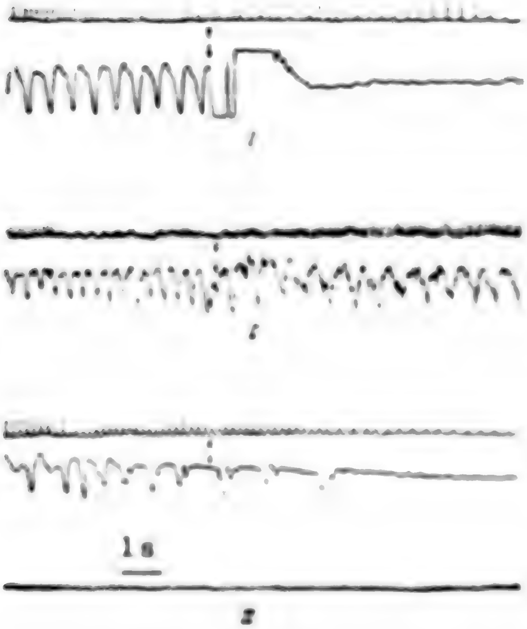

Figure 2.
Attenuation of inhibitory effects of stimulation of reticular formation on heart and respiration rate under the influence of accelerations in rats. Each segment illustrates the EKG and pneumogram; the arrow shows start of stimulation.

I) before rotation
II) 2d min of exposure to 8 G accelerations
III) 1 min after stopping centrifuge

There was consistent depression of inhibitory reticular influences on respiration and cardiac function under the effect of accelerations, and it was euqally demonstrable in anesthetized rats (regardless of type of anesthesia) and waking rabbits. The extent thereof increased with increase in level of accelerations. According to the mean data, there was a 45 and 75% decrease

in effect of stimulation of the reticular formation, in the form of bradycardia in rabbits, with exposure to 6 and 10 G accelerations, respectively; 8-10-fold accelerations induced statistically reliable and rather prolonged changes. According to the data in the Table, the most substantial changes in rats exposed to 10-fold acceleration were observed during rotation, when there was virtual disappearance of the inhibitory effect of stimulation of the reticular formation on cardiac and respiration rates. One minute after stopping the centrifuge, there was a tendency toward restoration, but reliable differences from background data still persisted; after 10 min, there were no significant differences from base values. It should be noted that the recovery process was more complex than demonstrable by the mean data. For example, intensification of bradycardia induced by stimulation of the reticular formation was a rather typical phenomenon in the aftereffect period (Figure 3B). Usually there was more complete recovery by the 20th-30th min after stopping the centrifuge.

Effect of accelerations on inhibitor influence of stimulating the rat's mesencephalic reticular formation (M±m)

Parameter	Number of cases	Parameter change during stimulation, % of base value			
		before rotation	2d min of exposure to 10 G	after stopping	
				1 min	10 mi
Rate of cardiac contractions	31	68.0±3.4	94.2±2.2*	84.5±3.9*	69.4±7.8
Rate of respiratory excursions	12	35.7±11.6	89.9±11.3*	76.3±10.0*	54.3±18.7

*$P<0.05$, as compared to prerotation data.

With regard to evaluation of the effects of accelerations on the excitatory and inhibitory influences of stimulation of the reticular formation, the changes in heart rate of rabbits are of particular interest (Figure 4). In this animal species, stimulation of the reticular formation induced mostly a biphasic reaction: significant bradycardia during stimulation and a tendency toward tachycardia in the poststimulation period. During rotation against the background of tachycardia, there was a sharp decrease of the change in the direction of lower heart rate, whereas there was an equally drastic change in the direction of increase, and it became statistically reliable. During the aftereffect period following exposure to accelerations, there was restoration of the phase of bradycardia, while poststimulation tachycardia disappeared. Consequently, with exposure to accelerations, there is a rather distinct opposite nature of change in excitatory and inhibitory influences of the mesencephalic reticular formation on cardiac function. Typically enough, there is enhancement of excitatory effects, i.e., effects in the same direction as the influence of accelerations.

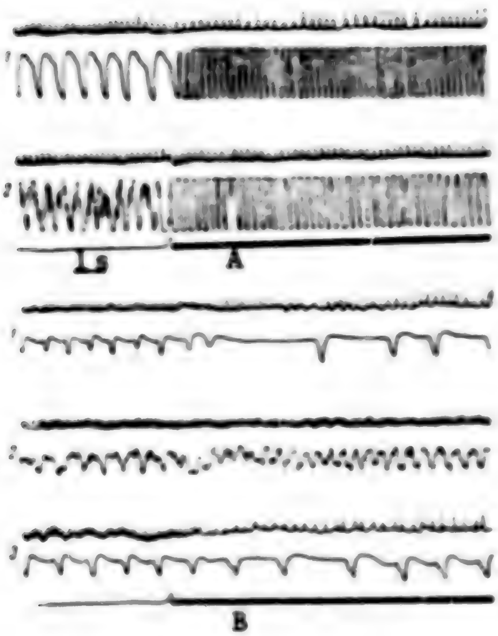

Figure 3.
Different variants of change in cardiac and respiratory components of reaction to stimulation of the reticular formation under the influence of accelerations

A, B) experiments on different rats.

Here and in Figure 4:
1) before rotation
2) 2d min of exposure to 10 G
3) 10 min after stopping centrifuge

Each segment (1, 2 and 3) illustrates the EKG and pneumogram; the bottom curve in A and B refers to stimulation

The obtained data did not enable us to derive an analogous conclusion with respect to the respiratory system. We failed to demonstrate consistent changes in the effect of stimulation of the reticular formation, in the form of acceleration of respiratory excursions. During rotation, the rate thereof usually remained the same, but the magnitude fluctuated significantly in different animals. Evidently, we can refer to two circumstances to explain the causes of this phenomenon.

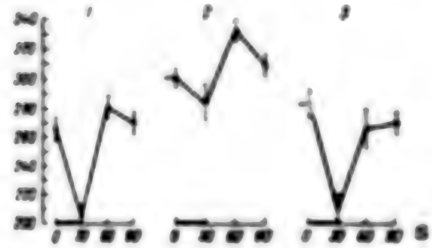

Figure 4.
Effect of accelerations on change in heart rate induced by stimulation of the rabbit's reticular formation

X-axis, time after start of stimulation of reticular formation (s); the boldface line refers to a 30-s period of stimulation; y-axis, heart rate, per min

In the first place, it must be noted that accelerations induce very strong excitation of hte respiratory system. During rotation, the respiratory rate sometimes increases to 200% the base level. The effect of stimulation of the reticular formation is attenuated against such a background. However,

one never observes inversion of the respiratory reaction, and restoration of level thereof occurs immediately after the centrifuge is stopped, with normalization of the background. In the second place, one must take into consideration mechanical difficulties in performing a respiratory excursion during exposure to transverse accelerations, which can apparently create certain restrictions for such a reaction as acceleration of respiratory excursions.

Thus, electrical stimulation of the mesencephalic reticular formation during exposure to transverse accelerations of 6-10 G elicited changes in its influence on cardiac function and external respiration. This applied the most to inhibitory influences, the intensity of which was drastically reduced. We do not have sufficient grounds to relate these changes to functional impairment of the reticular formation. The electrographic findings (appearance of regular Θ-rhythm, depression of slow Δ-oscillations) were indicative of an increase in its functional activity under the influence of accelerations. Moreover, there was substantial decrease, or even inversion of the inhibitory effects of stimulation, while the excitatory ones were mostly retained and could even become more marked. In the literature, the possibility of manifestation of inhibitory and excitatory influences on autonomic functions during electrical stimulation of mesodiencephalic structures of the brain is attributed to involvement of different elements on the bulbar level and both branches of the autonomic nervous system [10, 11]. The peripheral effect demonstrated is interpreted as the result of complex interstructural interaction, the nature of which is largely determined by incoming afferentation. In the light of these conceptions, the changes we demonstrated could be attributed to a change in reticular regulatory influences due to a change in conditions under which the circulatory and respiratory systems function as a result of elevation of hydrostatic blood pressure, difficulty of external respiratory function and other adverse effects of accelerations. As we know, with exposure to accelerations the involvement of adaptive and compensatory mechanisms leads to stimulation of the cardiovascular and respiratory systems [8, 9]. Under these conditions, apparently there is depression of opposite reactions that are not advantageous to the body. In this respect, inversion [distortion] of "Parin's discharge [unloading] reflex" is demonstrative: elevation of pressure in the pulmonary circulation under the influence of transverse accelerations leads to elevation of arterial pressure and higher pulse rate [12], rather than an adequate response in the form of bradycardia and hypotension.

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SIGNIFICANCE OF THE VIBRATION COMPONENT TO THE DELETERIOUS EFFECT OF IMPACT ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 51-54

[Article by G. P. Mirolyubov, V. A. Elivanov and G. P. Stupakov, submitted 17 Jan 78]

[English abstract from source]

Animal experiments demonstrated that damped oscillations of the support construction induced by impact accelerations enhanced their damaging effect on dogs. Within the frequency range tested -- from 20 to 178 Hz -- the threshold of lesions of the lungs, heart and liver decreased and reached 34% at a frequency of 85 Hz. The level of liver lesions was inversely proportional to the frequency of the support oscillations. Lesions of the lungs and the heart were more expressed at 85 Hz and decreased with an increase or a decrease of the oscillation frequency. At a frequency of 130—176 Hz the effect of the vibration component was not seen.

[Text] In view of the constant improvement of flight performance of manned craft and complexity of fights, there is an increased need to refine methods for rescuing crew members and, in particular, methods of protecting them from the effects of impact accelerations that appear in the case of an emergency landing.

Heretofore it was believed that the deleterious effect of impact accelerations is substantially related to its three parameters: maximum magnitude ("maximum acceleration"), time of exposure and rate of build-up.

This does not take into consideration the fact that accelerations to which a pilot is exposed are often oscillatory in nature. The oscillations are attributable mainly to damped vibrations of the pilot's seat, which is excited under the influence of the impact. In practice, it is very difficult to attenuate vibration, for example, by increasing the rigidity of the seat. At the same time, there have been virtually no studies of the effect of the vibration component of impact accelerations on endurance of the latter.

In a study conducted on rats, it was demonstrated that vibration of support structures could significantly enhance the effect of impact accelerations

[1]. When animals placed on a resilient base landed at the rate of 6 m/s, they died as a result of extensive damage to their viscera. When they were placed on a rigid support, no injuries occurred, even at a landing rate of 14 m/s.

Still unknown is the extent to which the deleterious effect of the vibration component of impact accelerations is manifested in animals that are larger than rats (in particular, dogs) and how it depends on the parameters of this component of impact accelerations, as well as the qualitative distinctions thereof. We conducted experiments on dogs in order to answer these questions with regard to the effects of impact accelerations in a transverse direction, in relation to the body, with which injuries to the viscera determine endurance.

Methods

We used young dogs of different breeds and both sexes weighing 5-8 kg. Impact accelerations were generated on a special stand by stopping a large falling platform with deformable lead cylinders (crushers). The rate of drop of the platform when stopping thereof began was constant and constituted 12.5 m/s. The required level of accelerations was obtained by selecting a crusher of a specific size.

Damped oscillations of the seat were simulated by means of resilient supports excited by impact accelerations. These resilient supports consisted of removable steel plates securely attached at both ends to large braces installed on the stand platform. The required oscillation frequency was produced by proper selection of plate thickness.

The animals were put on the plate on their belly. The body was so placed as to have maximum amplitude of vibration in the region of the center of gravity, and it diminished in the direction of the head and pelvis. The head was put on the brace, and it was not exposed to the direct effect of vibration. The head was partly protected against impact accelerations by a shock-absorbing liner. A special system of tapes provided for relatively uniform contact of the animal's body with the plate.

At the moment of landing, we recorded the displacement of the center of the plate in relation to the platform, accelerations to the plate (impact-vibration accelerations) and to the platform (impact accelerations).

In all, we conducted 70 experiments, in 49 of which the animals were put on a resilient support, which oscillated at frequencies of 20 to 176 Hz, and exposed to accelerations of 165 to 237 units, with a damping index of 0.09 to 0.24. In 21 control experiments, the animals were on a rigid support, directly on the platform of the stand.

The damping coefficient was calculated using the following formula:

$$E = \ln\left(\frac{y_i}{y_i + 1}\right)_{cp} \cdot \frac{1}{\pi} \cdot \frac{T_0}{T_\text{д}}.$$

where T_0 and $T_\text{д}$ are the periods of natural and damped oscillations, respectively $(y_i/y_i + 1)_{cp}$ is the arithmetic mean of relations of adjacent amplitudes of damped oscillations [2].

In all of the experiments, impact accelerations on the platform were of the same type and characterized by uniform build-up to a maximum level (90-240 units) followed by a sharp drop. Accelerations lasted 0.014-0.025 s.

Damage to the viscera was detected mainly macroscopically at autopsy of the animals immediately after sacrificing them by means of exposure to a mixture of ether and chloroform fumes immediately after exposure to accelerations.

The severity of lesions was assessed in arbitrary units according to a specially prepared scale for the most traumatized organs, the liver, lungs and heart. The gradation took into consideration the size and number of lesions (effusions of blood, ruptures).

The digital data were submitted to statistical processing according to Fisher-Student, while the U criterion was used to determine the reliability of differences in severity of damage to viscera of animals in different groups.

Results and Discussion

In the first series of experiments, determination was made of the deleterious effect of accelerations as related to frequency of support oscillations stimulated by the impact. Impact accelerations on the platform remained constant, constituting a maximum ($n_{max.pl.}$) of 163±8 units and lasting ($t_{pl.}$) 0.015-0.017 s, with the animals on a rigid support (control experiments), and they induced only minimal visceral damage: isolated petechial hemorrhages and small focal (up to 1.5×1.5 cm in size) hemorrhages in the lungs.

Figure 1 shows that impact-vibration accelerations of 23-110 Hz were associated with more marked damage to internal organs than impact accelerations in the control experiments. With oscillations of 131 and 176 Hz, the extent of damage was virtually the same as in the control.

The mean rating of damage to the liver at frequencies of 23 to 85 Hz, to the lungs and heart at 85 Hz was different, with statisticaly reliability, that in the control and in experiments with support oscillation frequency of 176 Hz ($P<0.01$).

There was no appreciable difference in lesions to the liver at frequencies of 23, 46, 85 and 110 Hz, and they usually consisted of isolated, focal,

subcapsular hemorrhages (1×1 cm in size) and ruptures of the parenchyma with the capsule (up to 4) up to 1.5 cm in length (grade II). In some cases, there were multiple ruptures (2-3 per lobe) over 1.5 cm in length (grade III).

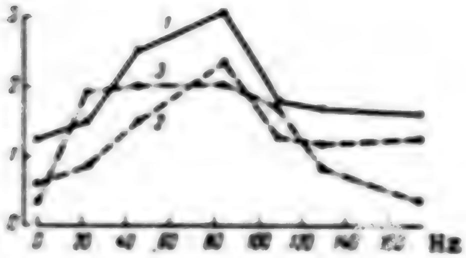

Figure 1.
Severity of lesion to the lungs (1), heart (2) and liver (3) of dogs as a function of frequency of vibration (f) of the support with constant accelerations on the platform (control data are given for f = 0).

Here and in Figure 2: x-axis, vibration frequency (Hz); y-axis, severity of lesion (arbitrary units)

Damage to the lungs and heart was the most severe with vibrations of 85 Hz; it was manifested in the lungs in the form of confluent focal effusions of blood up to 4 cm in diamter each, occupying less than one-third the surface of the lungs (grade III) and occasionally more (grade IV); in the heart, it was manifested in theform of isolated (up to 5), petechial subepicardial hemorrhages, mainly in the right atrium (grade II) and occasionally small hematomas (up to 5 mm) extending over the entire thickness of the atrial wall.

In the second series of experiments we studied the level of impact accelerations on the platform, at which a minimal deleterious effect appears in dogs placed on a resilient support, and determined the correlation between levels of impact and impact-vibration accelerations.

Appearance of minimal traumatic lesions in dogs as related to accelerations on platform, resilient support and frequency of vibration of the latter

Statistical index	Accelerations, units				
	control	vibration, Hz			
		46, 85 and 110		176	
		on platform	on support	on platform	on support
$M \pm m$	168,2±1,75	128,5±8,04	172,9±11,6	160,0±3,08	186,0±4,11
P	—	<0,001	>0,1	>0,05	<0,05
% of control	—	76,2	102,8	95,2	110

With support vibrations of 46, 85 and 110 Hz, minimal damage appeared with accelerations on the platform an average of 23.8% lower than without vibration of the support (P<0.01) (see Table). At a frequency of 85 Hz (4 experiments), this difference increases to 34% (P<0.01). However, the maximum acceleration on a resilient support was higher than on the platform, approximating, on the average, the accelerations in control experiments.

Consequently, in the indicated range of frequencies, vibration of the support worsened considerably the landing conditions for animals, and relative increase in maximum acceleration on the resilient support was a contributory factor.

In order to determine the correlation between the deleterious effect and vibration frequency, with a constant level of impact-vibration acceleration, we conducted a third series of experiments. In these experiments, maximum level of impact-vibration accelerations was held at 225 units, with no more than 7% deviation. With increase in frequency of oscillation of the support the intensity of damping thereof diminished, as indicated by a decline of the damping coefficient (from 0.24 to 0.09).

Damage to the liver was the most consistently appearing and life-endangering finding. A comparison of severity thereof revealed that it is inversely related to frequency of vibration of the support (Figure 2). With extreme frequencies in the tested range (20 and 130 Hz), the damage was marked and statistically reliable (P<0.05).

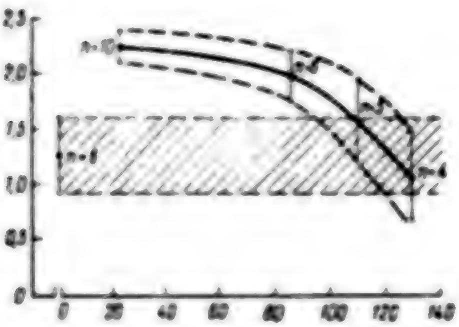

Figure 2.
Severity of liver damage in dogs as a function of vibration frequency, with constant maximum acceleration level on support. The dots refer to mean values in groups; vertical segments indicate mean errors and n refers to number of cases.

With vibrations at a frequency of 130 Hz, the extent of damage to the liver was close to the control level (somewhat less than the latter), which is indicative of the lack of influence thereof at this frequency. The difference between mean values for degree of damage at a frequency of 130 Hz and in the control tests of this series is attributable to the fact that, for technical reasons, accelerations were somewhat higher, 233±9 units, in the latter case.

As a rule, the lesions appearing in the presence of vibrations did not differ from those in experiments without vibration, with respect to localization and nature. There was an exception: isolated (up to 5) petechial hemorrhages in the mitral valve cusps, which appeared in an average of 27% of the cases with exposure to vibration only.

From the practical point of view, significant intensification of the deleterious effect of impact-vibration accelerations on the liver and decrease in frequency of their vibration component are the most important factor. This tendency, in the tested range of frequencies, apparently extends to man also. One could have expected appreciable differences mainly with regard

to the mechanisms of appearance of lesions as a result of resonance of organs in the thoracoabdominal system [3]. We do not have data concerning the resonance frequency of this system of canine organs. However, on the basis of the correlations of body mass and the fact that, in man, resonance appears at 4-7 Hz [3, 4] and in rats, at 18-25 Hz [3], it can be considered that we tested frequencies significantly above resonance levels, and the phenomenon in question was absent. This is also confirmed by the lack of appreciable differences in nature and localization of lesions with exposure to accelerations with and without a vibration component. At the same time, the mechanisms of enhancement of the deleterious effect of impact-vibration accelerations on the organism require further investigation. In particular, the causes of increase in damage to the lungs and heart at 85 Hz frequency of vibration o. the support are not clear.

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EFFECT OF RESTRICTED ACTIVITY ON VESTIBULAR FUNCTION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4 1979 pp 55-58

[Article by G. I. Gorgiladze, G. I. Samarin and G. S. Kazanskaya, submitted 16 Jul 76]

[English abstract from source]

The hypokinetic effect on the nystagmic reaction and illusory sensations upon caloric and galvanic stimulations of the labyrinths was studied on six test subjects (professional gymnasts). Under normal conditions the sportsmen predominantly showed the nystagmic response to the caloric irritation of the left labyrinth. A 10-day hypokinetic exposure produced a noticeable decrease of the above asymmetric nystagmic reaction to the caloric irritation of both labyrinths. Simultaneously an enhancement of illusory sensations and a decrease of their thresholds in response to the direct current labyrinthine stimulation were noted. The above changes can be attributed to the hypokinesia-induced decline of mechanisms of vestibular adaptation of sportsmen.

[Text] Long-term restriction of mobility induces impairment of activity of different functional systems. The vestibular function also undergoes certain changes, manifested by poorer endurance of angular and linear accelerations [1-4]. Animals lose the capacity for gradual reduction of the nystagmic reaction of the eyes to periodically recurring angular accelerations, i.e., for habituation, a process upon which vestibular conditioning is based [5].

These studies were conducted in order to investigate the influence of limiting motor activity on the functional state of the vestibular system of individuals with a high degree of vestibular stability.

Methods

The studies were conducted on 14 male volunteers ranging in age from 18 to 23 years. Six of them had engaged in athletic gymnastics for 4-8 years and had athletic ratings ranging from first class to Master of Sport. To restrict their activity, the subjects were put on strict bed rest (clinostatic hypokinesia). They had to maintain exclusively a horizontal position, with the head somewhat elevated on a pillow; they were not allowed to make abrupt movements, particularly with the lower extremities. The

other eight subjects did not have any special athletic training, and they constituted the control group. They were not submitted to hypokinesia.

The caloric and galvanic methods of stimulating the labyrinths were used to stimulate the vestibular system. The studies were conducted in the dark, with the subjects' supine and their eyes closed. Caloric stimulation was delivered using a previously described device [6]. The head of the subject was on a special head rest, which raised to 30° forward so that the horizontal semicircular canals would be in horizontal position, which is the best for caloric stimulation (Figure 1). The acoustic meatus was irrigated with water (120 mℓ, 30°C temperature) for 18 s. A special instrument was used for direct current stimulation of the labyrinths, which made it possible to stimulate the labyrinths with evenly building up direct current, precluding the unpleasant extralabyrinthine sensations related to abruptly increasing current. Current was delivered to the labyrinths by means of flat, chlorine-treated silver electrodes 10 mℓ [sic] in diameter, which were applied with a steel spring clamp to the temples, in front of the tragus.

Figure 1. Caloric stimulation of the labyrinth. A helmet is put on the subject's head, to which tubes are attached by means of special devices, to deliver water into the meatus.

An electronystagmogram (ENS) was recorded from the external margins of the orbits on an 8-channel encephalograph. Appearance of illusional perceptions was also recorded; for this purpose, brief subjects depressed a special button upon appearance of specific sensations (turning, bending, rotating, etc.). After completing the tracing, the subjects were questioned verbally about the nature of these sensations. The ENG indicated the total number of nystagmic beats and duration of the reaction. In the galvanic tests, determination was made of threshold level of current required to induce illusory perceptions in response to binaural and bipolar galvanization of both labyrinths (cathode on the right side and anode on the left). The studies were made 1 day before hypokinesia (background data) and on the 10th day of bed rest.

Results and Discussion

Caloric tests: The nystagmic reaction of the eyes fluctuated over a wide range in gymnasts, with regard to total number of nystagmic oscillations and duration of the reaction. Minimum and maximum number of nystagmic responses ranged from 65 to 229, and duration of the reaction, from 60 to 152 s. There were even greater differences in response to the right and left caloric test in the same subjects. Thus, nystagmus in response to calorization of the right labyrinth of 1 subject lasted 60 s (65 nystagmic beats) and 156 s in response to calorization of the left labyrinth (319 beats). All subjects presented dominance of a reaction on the left: total number of nystagmic beats constituted a mean of 205.8 ± 27.4 and duration of the reaction, 123 ± 10.1 s. On the right, the figures were 124.5 ± 19.1 and 93.2 ± 7.0 s, respectively Figure 2). This asymmetry was statistically reliable for both parameters of nystagmus ($P<0.05$).

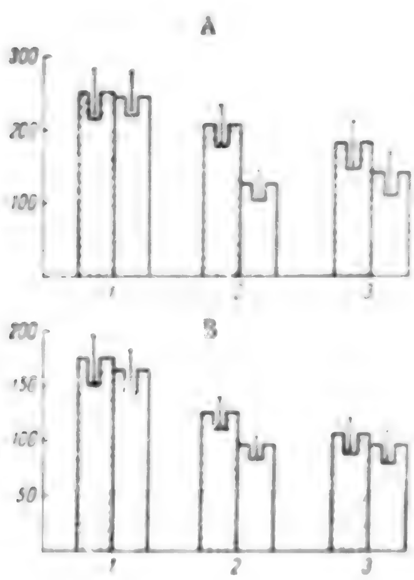

Figure 2.
Graphic illustration of total number of nystagmic beats (A) and duration of nystagmus (B) in the control group of subjects (1), in athletes prior to hypokinesia (2) and on the 10th day of hypokinesa (3)

Here and in Figure 3: striped columns refer to reaction to caloric test on left labyrinth and white columns, on the right labyrinth. The vertical lines refer to one standard error.

In the control group of subjects, the nystagmic response to the caloric tests on the labyrinths was characterized by the following parameters: total nystagmic beats constituted 253.5±27.7 and reaction time was 165.3±18.4 s in the caloric test on the right labyrinth, the figures were 257.3±33.2 and 174.0±22.8 s, respectively, for the left labyrinth (see Figure 2).

Caloric stimulation of the labyrinths was associated with appearance of illusory movements of diverse nature, in addition to the nystagmic reaction. In gymnasts, this was usually mild and consisted of a sensation of mild vertigo of an indefinite nature (1 subject), negligible turns of the body in the horizontal plane (1 subject) or about the longitudinal axis of the body by 45-70° (2 subjects). There were no illusory sensations in response to caloric stimulation of the labyrinths in two subjects. The illusions appeared with a longer latency period in response to the caloric test on the left labyrinth than on the right (a mean of 22.0±4.8 versus 18.5±2.5 s). They also lasted longer in response to heating on the left (a mean of 14.8±4.0 versus 12.0±3.1 s on the right). In the control group, all subjects experienced distinct illusional sensations to heating of both labyrinths; in 4 subjects, the seeming movements were in a horizontal plane and in 3, about the longitudinal axis of the body. One subject had more complex illusions: first the sensation of turning about the longitudinal axis of the body, to which was subsequently added the sensation of rotating in a horizontal plane. Illusions appeared with a latency period of 28.1±3.4 s and lasted 50.0±11.3 s in response to the caloric test on the right labyrinth, the figures for the left labyrinth being 26.9±3.1 s and 54.3±8.8 s, respectively (Figure 3). In most cases, the seeming rotation in the horizontal plane was rated rather intensive, in the form of 2-4 complete turns about the dorsoventral axis of the body, traversing the region of the pelvis, chest or neck.

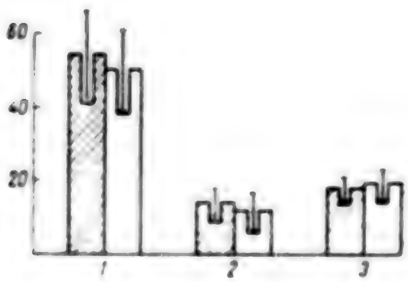

Figure 3.
Graphic illustration of duration of illusions in control group (1), athletes beforehypokinesia (2) and on 10th day of hypokinesia (3)

The nystagmic reaction underwent the following changes on the 10th day of hypokinesia: there was an increase in total number of nystagmic beats in response to heating the right labyrinth of 3 subjects, as compared to the base values, and it decreased negligibly in the others. The decrease in the reaction was more significant than increase thereof in response to heating the left labyrinth (mean total number of nystagmic beats constituted 144.2±28.0 on the right and 180.2±31.6 on the left). There was an

analogous change in duration of nystagmus (95.6 ± 11.5 s on the right and 104.5 ± 12.6 s on the left). This circumstance, namely attenuation of the reaction on the left and enhancement on the right, led to attenuation of asymmetry of nystagmus, and dominance of the reaction on the left was unreliable ($P>0.05$) (see Figure 2).

Bed rest for 10 days led to significant changes in illusory sensations, manifested primarily by the fact that illusions appeared in 2 subjects who did not experience them prior to hypokinesia. The other four subjects reported considerable intensification of illusions. In response to the caloric test on the right labyrinth, illusions appeared with a mean latency period of 31.3 ± 3.6 s, and they lasted 19.5 ± 4.0 s; the figures were 32.3 ± 4.2 and 18.5 ± 3.3 s, respectively, for the left labyrinth (see Figure 3).

Galvanic tests: The threshold levels of direct current required to induce illusions were extremely high for gymnasts (5-7 mA). They consisted of a sensation of movements in the form of turning, bending, rotating in the horizontal plane or about the longitudinal axis of the body. On the 10th day of bed rest, they presented a distinct lowering of thresholds of appearance of illusions in response to galvanic stimulation of the labyrinths. They appeared with a current of 3-4 mA. In the control group of subjects, illusional sensations in response to binaural, bipolar stimulation of the labyrinths appeared with a current of 1.27 ± 0.18 mA.

Thus, these stuides revealed that in athletes, unlike subjects without athletic training, nystagmus is characterized by distinct asymmetry in response to stimulation of the two labyrinths with the same caloric tests, while illusory sensations were either absent or mild. Such prevalence of vestibular reactions to stimulation of one labyrinth over the reactions to stimulation of the other were demonstrated in pilots, figure skaters and classical ballet dancers, i.e., individuals for whom intensive vestibular stimulation is a significant element of their routine occupational activity [7-8]. The thresholds of appearance of illusions in response to electric stimulation of the labyrinths with direct current were considerably higher in athletes than in individuals of the control group. Evidently, these distinctions of vestibular reactions of gymnasts should be interpreted as a manifestation of habituation, which developed as a result of training.

There is some information in the literature concerning variability of caloric nystagmus and thresholds of appearance of illusions in response to galvanic stimulation of the labyrinths, which was obtained on untrained hyplinetic subjects. Unfortunately, it is difficult to analyze these data, since they do not include a description of test conditions or digital material, and in a number of cases the obtained figures are diametrically opposed [1, 2, 4].

As a result of 10-day hypokinesia, there were substantial changes in vestibular function: attenuation of dominance of one labyrinth, appearance or intensification of illusory sensations and decrease in thresholds of their appearance. These changes should apparently be attributed to the fact that

hypokinesia, which is a rather strong deconditioning factor for different functional systems of the body, leads to weakening of mechanisms of vestibular habituation.

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EFFECT OF ROCKING ON ABSORPTION OF SOME GROUP B VITAMINS AND ASCORBIC ACID IN THE SMALL INTESTINE OF DOGS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 59-62

[Article by R. P. Faytel'berg and T. V. Gladkiy, submitted 10 Jan 77]

[English abstract from source]

On the dogs with a Thiry Pavlov fistula (an isolated loop of the small intestine) the effect of 30-min acceleration on the absorption of thiamine bromide, riboflavine, pyridoxine-hydrochloride and ascorbic acid as well as on the gastric juice secretion was studied. It was demonstrated that back to forth linear acceleration increased vitamin B_1 absorption, decreased vitamins B_2 and B_6 and ascorbic acid absorption, and altered secretion of gastric juice

[Text] There are data in the literature indicating that the digestive system is quite sensitive to accelerations [1, 2], and that there is relatively slow restoration of its initial state. There are isolated reports on the effects of gravitational accelerations and rocking on resorptive processes in the intestine [3, 4], and it was demonstrated that there is a change in absorptive function of the intestine also.

In particular, specific distinctions were noted in metabolism of vitamins under the influence of vestibular stimuli [5-7]. Several works report an increase in vitamin requirements (particularly B_1, B_2, B_6, C and PP) in individuals who are regularly engaged in flying and sailing [8, 9]. For this reason, providing the body with vitamins during the period of a vestibular load is an important factor of increasing resistance to accelerations.

The gastrointestinal tract is the main route of vitamin intake.

On the basis of the foregoing, it is very interesting to determine the effect of accelerations on absorption of vitamins in the gastrointestinal tract, and this article deals with a study thereof.

Methods

Chronic experiments on 4 dogs with a 20-cm segment of small intestine isolated according to Thiry-Pavlov were conducted to study absorption in the intestine of thiamin bromide, riboflavin, pyridixone hydrochloride and ascorbic acid in 30 min under normal conditions, with exposure to direction [sign] changing rectilinear accelerations for 30 min and 1 h after such exposure.

The tested vitamins were injected in the fistula (once a day) in the following amounts: 3 mg (200 μg/mℓ) thiamin bromide, 2 mg (125 μg/mℓ) riboflavin, 4 mg (250 μg/mℓ) pyridoxine hydrochloride and 60 mg (4 mg/mℓ) ascorbic acid.

We determined the degree of vitamin absorption from the difference between amount introduced in the intestine and eliminated from it. The vitamin B_1 level was assayed by the method of Wang and Harris [10], with prior precipitation of proteins with 20% trichloroacetic acid. Vitamin B_2 was determined by the method of Ye. M. Maslennikova and L. G. Gvozdova [11]; the colorimetric method was used for vitamin B_6, and ascorbic acid content was assayed according to S. M. Prokoshev [12].

In addition to studying absorption, we determined the influence of the tested vitamins on the secretory system of the intestine. For this purpose, we determined the amount of intestinal juice in fluid eliminated from the intestine (after 30-min presence of vitamin solution), on the basis of alkalinity, and we compared the obtained data to the alkalinity of spontaneously secreted gastric juice.

We used the four-bar swing of K. L. Khilov (rod length 3.5 m and swinging rate 16-18/min) to rock the experimental animals. They were rocked for 30 min.

In all, 240 tests and 490 readings were made in chronic experiments. The experimental results were submitted to statistical processing.

Results and Discussion

Absorption of thiamin bromide: Our studies revealed that a mean of 1093 ± 85.5 μg thiamin bromide was absorbed under normal conditions within 30 min in the small intestinal fistula in the dog named Mukhtar; this constituted 36.4% of the injected amount of vitamin; the figures for the dog Malysh were 884 ± 89.7 μg (29.4%).

Rocking the animals for 30 min increased absorption of vitamin B_1 to 53.6% in Mukhtar and 51.4% in Malysh, which was 47 and 74%, respectively, above normal.

There was some decrease in absorption of thiamin bromide 1 h after swinging, but it was 20.3% above normal in Mukhtar and 62% above normal in Malysh.

Absorption of riboflavin: Under normal conditions, a mean of 569±49.8 μg riboflavin was absorbed in 30 min in the intestinal loop of the dog Belka, which constituted 28.4% of the given dose of riboflavin; 416±77.7 μg (20.8%) vitamin B_2 was absorbed in the intestine of the dog Strelka.

During exposure to accelerations, there was no change in absorption of riboflavin, but 1 h after discontinuing swinging it diminished appreciably, constituting 373±26.6 μg in Belka and 396±65.5 μg in Strelka.

Absorption of pyridoxine hydrochloride: A mean of 70.0% of the given amount of pyridoxine hydrochloride was absorbed in the intestine of Mukhtar and 70.9%, in Malysh.

During swinging, we observed some (unreliable) decrease in absorption of B_6 in Malysh (to 60.5%), with no change in this index in Mukhtar.

Absorption of vitamin B in Mukhtar also remained unchanged 1 h after discontinuing exposure; in Malysh pyridoxine absorption decreased even more, constituting 54.8% of the given dose.

Absorption of ascorbic acid: Under normal condition, there was absorption of 50.8% of given amount of ascorbic acid in the fistula in Mukhtar, 64.2% in Malysh and 76.4% in Strelka.

We observed depression of ascorbic acid absorption during exposure to accelerations in only one dog out of three.

One hour after discontinuing exposure, there was even more decrease in absorption of ascorbic acid by Malysh, and it was 24.2% below normal; the other dogs also presented some decrease in absorption of vitamin C.

Secretory function of the small intestine during absorption of vitamins: When administered into an intestinal fistula, the tested vitamins stimulated secretion of gastric juice.

Administration of 3000 μg vitamin B_1 induced 375% increase in juice secretion in Mukhtar and 290% increase in Malysh. Significant intensification of secretion of gastric juice was observed in all of the dogs during absorption of riboflavin, pyridoxine hydrochloride and ascorbic acid (see Table).

With concurrent administration of vitamin B_1 and swinging, we observed changes in different directions in gastric juice secretion. Thus, while 7.1±0.99 mℓ juice was secreted under these conditions, or 86% more than with absorption of vitamin alone, in Mukhtar, there was no change in secretion of juice in Malysh. Examination of juice secretion 1 h after swinging revealed that it reverted to normal with absorption of vitamin B_1.

Secretory reaction of the intestine to administration of vitamins (B_1, B_2, B_6 and C) under normal conditions and during swinging (M±m)

Name of dog	Periodic secretion of juice in 30 min, mℓ	Gastric juice secretion (mℓ) with absorption of vitamins (in 30 min): normal	with 30-min swinging	1 h after swinging
		Vitamin B_1		
Mukhtar	0.8±0.26	3.8±0.28 (P_1<0.05)	7.1±0.90 (P_2<0.01)	4.2±0.33 (P_2>0.3)
Malysh	1.1±0.11	4.3±0.48 (P_1<0.001)	4.6±0.26 (P_2>0.8)	4.3±0.52 (P_2=1.0)
		Vitamin B_2		
Belka	2.5±0.19	6.6±0.38 (P_1<0.001)	6.3±0.61 (P_2>0.8)	5.9±0.23 (P_2>0.1)
Strelka	2.4±0.26	8.2±0.70 (P_1<0.001)	7.6±0.62 (P_2>0.2)	7.3±0.53 (P_2>0.2)
		Vitamin B_6		
Mukhtar	0.6±0.15	6.2±0.49 (P_1<0.001)	5.8±0.54 (P_2>0.5)	5.4±0.22 (P_2>0.1)
Malysh	1.2±0.18	5.0±0.20 (P_1<0.001)	4.9±0.24 (P_2>0.7)	6.0±0.41 (P_2<0.05)
		Vitamin C		
Mukhtar	1.0±0.15	9.4±1.34 (P_1<0.001)	8.2±0.57 (P_2>0.2)	9.9±0.43 (P_2>0.5)
Malysh	1.8±0.18	7.5±0.78 (P_1<0.001)	8.6±0.35 (P_2>0.5)	12.5±0.65 (P_2<0.01)
Strelka	5.0±0.21	8.4±0.55 (P_1<0.001)	8.8±0.42 (P_2>0.5)	12.3±0.56 (P_2<0.001)

Key:

P_1) significance of differences between mean amounts of periodically secreted gastric juice and juice secreted with absorption of vitamins

P_2) significance of differences between mean amounts of secreted juice with absorption of vitamins under normal conditions and during swinging

There was no change in secretion of gastric juice during swinging against the background of administration of riboflavin. However some decrease in secreted juice was observed 1 h after swinging: by 11% in Belka and Strelka.

No reliable changes in secretion of gastric juice were demonstrated during swinging and concurrent administration of vitamin B_6. But after 1 h, there was a 13% decrease in juice secretion in Mukhtar and 20% increase in Malysh.

Intensification of juice secretion was observed 1 h after swinging against the background of vitamin C. It was 5% above normal in Mukhtar, 66.7% above normal in Malysh and 46.1% above normal in Strelka (see Table).

The obtained data indicate that exposure of the body to rectilinear accelerations in different directions [of different signs] alters vitamin absorption in the canine intestine. It should be noted that the effect of swinging is not necessarily manifested during its action, and it is the most marked after 60 min.

The fluctuations of parameters of absorption and secretion observed during swinging, in the presence of the same substance in the dog's intestine, could be attributed to differences in dogs' sensitivity to motion sickness. In spite of this, we can demonstrate a tendency toward change in vitamin absorption under the influence of swinging: increase in thiamin absorption and, on the contrary, decrease in absorption of riboflavin, pyridoxine hydrochloride and ascorbic acid.

The increase in absorption of some vitamins and decrease in others under the influence of swinging could be attributed to different routes of transport thereof. Some of them are activated and others are depressed [13-16].

Introduction of vitamins in the intestine induces significant increase in secretion of gastric juice, as a result of their stimulating effect on the intestinal mucosa. Swinging impairs secretion when vitamins are present in the intestine, and this could have an adverse effect on resorptive processes.

Thus, it may be assumed that impairment of resorptive processes in the intestine is one of the causes of vitamin imbalance in the body, which is observed after exposure to accelerations [5, 8, 9].

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ULTRASTRUCTURE OF LYMPH NODES OF DOGS EXPOSED TO LONG-TERM EXTERNAL GAMMA RADIATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 62-66

[Article by V. V. Shikhodyrov, L. A. Bespalova and V. S. Romanov, submitted 15 Feb 77]

[English abstract from source]

The purpose of the present investigation was electron microscopic study of lymph nodes of dogs exposed to chronic gamma irradiation during 6 years [illegible] a total dose of 125 rad/year. The exposure induced changes in the cell composition of the paracortical regions due to a decrease of the count of small lymphocytes and a predominant increase of young blast cells with an altered ultrastructure. Chronic gamma irradiation led to an increase of the number of plasma cells and emergence of intermediate cell forms due to plasmatization of lymphocytes and reticular cells.

[Text] Considerable material has been accumulated to date concerning the special pathogenetic significance of condition of lymphoid tissue in formation of the general signs of damage to the body from exposure to low doses of external γ-radiation [1-3].

Our objective here was to evaluate the submicroscopic state of cellular elements of canine lymph nodes over a period of 6 years of constant exposure to γ-radiation in doses close to the radiation background under space flight conditions [4]. This is a part of a large set of studies dealing with evaluation of the effects on animals of chronic exposure to low doses of γ-radiation [5, 6].

Methods

We studied the tissue of cervical lymph nodes of dogs. Ten dogs were submitted to chronic ^{60}Co γ-radiation for 6 years. The annual exposure dose constituted 125 rad. Against the background of chronic irradiation (dose rate 62.5 rad/year), 8 animals were exposed once a year to an additional radiation load of 58 rad in 20 h (3 "bursts": 42+8+8 rad). Concurrently with experimental animals, we sacrificed 1 control dog after 2, 3, 4, 5 and 6 years.

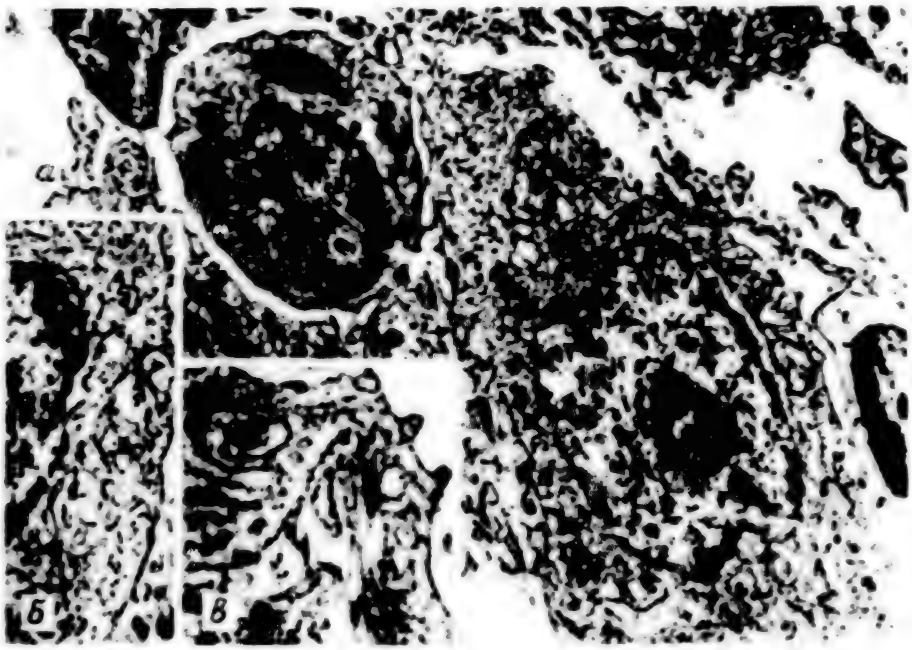
Sections of pulp, mainly from the paracortical regions of the lymph nodes, were taken for electron microscopy. The material was fixed in buffered glutaraldehyde and 2% osmium according to Millonig. The preparations were imbedded in epon. Ultrafine sections were prepared on an LKB ultratome. They were contrasted according to Reynolds. Photographs were taken using a UEMV-100K electron microscope and the Japanese Jem-100B microscope.

Results and Discussion

At the early stages of the experiment (2-3 years), there were negligible deviations from normal of most lymphocytic parameters, with regard to ultrastructural organization of the nucleus and cytoplasm: appearance of nuclear invaginates, clearing of some parts of the cytoplasm, increased number of free ribosomes and elements of the endoplasmic system (EPS), as well as a marked reduction of "excrescences" of the cytoplasmic membrane. Such ultrastructural changes in lymphocytes were noted by a number of authors in the case of other types of radiation, and they were characterized as the primary reaction to radiation [7-9]. Signs of lymphocyte destruction were demonstrated only with the use of additional radiation loads, and they were probably due to the rhythm of radiation used, since the intervals between "bursts" were not long enough for total repair of structures.

There was an increase in number of plasma cells after 2 and, particularly, 3 years of chronic exposure to γ-radiation. Occasionally, there were entire clones of plasma cells which, according to development of the endoplasmic reticulum, were at different stages of maturation [10]. There was appreciable intensification of vacuolization processes in the cytoplasm. As a rule, the mitochondria did not undergo structural changes. The canaliculi of the rough endoplasmic reticulum were dilated in most plasma cells, and they were filled with well-visualized fine-grain substance; marked dilatation of EPS cisternae adjacent to the perinuclear zones was a typical finding in irradiated plasmocytes. The wide diversity of ultrastructural forms of plasmocytes was not only related to functional differences in the secretion process, but probably reflected postradiation changes in the form of faster differentiation of this class of cells. Appearance of many young, actively secreting forms of plasma cells coincides with the immunomorphological data, which indicate that there is an increase in number of cells synthesizing specific antibodies [2].

There was an increase in number of reticular cells in lymph nodes after 3 years of chronic irradiation. There was a tendency toward decrease in number of membrane components of the endoplasmic reticulum structures, with appearance of bleb-like forms and increase in number of free ribosomes and polysomes. In the case of irradiation with additional radiation loads, signs of increased phagocytic activity (formation of numerous bulges in cell membranes, increase in number of lysosomes and pinocytotic vacuoles in the cytoplasmic processes) were observed in the reticular cells. After 4 years of continuous γ-irradiation, there was prevalence of poorly differentiated forms of the blast type, reticular and plasma cells, as a result of decrease in number of "mature" lymphocytes in the lymph nodes.



Sections of dog's lymph node after 4 years of chronic γ-irradiation

а) lymphoblast, 9000×
б) segment of lymphoblast cytoplasm, 10,000×
в) segment of cytoplasm of a reticular cell, 15,000×

The blast forms were characterized by a clear large nucleus and delicate chromatin structure (see Figure, а). The nucleoli in young lymphocytes (blasts) were hypertrophied more often than under normal conditions. The cytoplasm of such cells was more abundantly and extensively supplied with organelles due to an increase in number of polymorphic mitochondria, as well as free ribosomes and polyribosomes which determine their pyroninophilia (see Figure, б). At this stage of the experiment, the plasma cells were, as before, extremely heterogeneous in structure. Against the background of a large number of free ribosomes and polysomes, small cisterns of granular EPS resembling that of plasma cells were formed in the cytoplasm of reticular cells (see Figure, в). Assessing this change as one of the compensatory and adaptive reactions, it may be assumed that long-term exposure of dogs to low doses of chronic radiation could lead to stimulation of blast transformation of lymphocytes and appearance of more resistant cell forms, with relatively high repair capacity [7]. This fact is quite

consistent with and supplements, to some extent, the results of immunomorphological studies conducted on the same dogs, which indicated intensification of phytohemagglutinin-blast transformation of peripheral blood lymphocytes [1].

Along with the known cellular elements of lymph nodes, atypical cells were demonstrated after 4-5 years of chronic γ-irradiation, and they were apparently transitory forms. Unfortunately, no clearcut differences have yet been demonstrated on the submicroscopical level between lymphoblasts, plasmoblasts and primitive reticular cells [7, 10, 11]. We can only assume that plasma cells were formed during chronic irradiation not only as a result of development from plasmoblasts, but apparently transformation of lymphocytes. Appearance of a large number of pyroninophilic cells [2], which a number of authors consider to be the first stage of lymphocyte differentiation in the direction of the plasma series [10-12], is in favor of this hypothesis.

Marked depletion of reticular storma with regard to lymphoid elements, relative increase in reticular cells and appearance of numerous regions of collagen fibrils constituted the main distinction of ultrastructural organization of lymph nodes of dogs exposed to chronic γ-radiation for over 5 years.

The method of electron microscopy we used was found to be informative enough for the study of lymph nodes, since it enabled us not only to to demonstrate the cellular composition of the selected segments, but differentiate more accurately between different types of cells, degree of their maturity and submicroscopic change in the course of long-term chronic irradiation. The obtained data revealed that processes of submicroscopic reorganization and adaptation of lymphoid tissue may be considerably extended in time during long-term continuous, chronic exposure to γ-radiation. This circumstance enabled us to track the ultrastructural reaction in different types of cells of the lymph nodes studied. Analysis of submicroscopic changes in cells of different types revealed a rather complex mechanism of action of chronic radiation at a low dose level, since the constant succession of cell generations in the course of 6-year irradiation made it impossible for a cell (or pool) to accrete specified cumulative doses of chronic radiation. Atrophy of the cortex of lymph nodes did not occur as a result of mass-scale death of lymphocytes (which was usually observed with delivery of larger doses of radiation); rather, it was probably the result of constant inhibition of formation of new lymphocytes, impaired maturation and differentiation thereof. In favor of this assumption is also the appearance of ultrastructural changes in younger cells (blasts), as well as the increase in plasma cells and "plasmatized" lymphocytes.

Thus, the mechanism of radiation effect of chronic γ-irradiation in low doses apparently consistent of a stimulating influence on processes of faster aging, which were characterized by gradual aplasia of lymphoid tissue, faster differentiation of plasma cells and collagenization of reticular stroma.

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SOME OF THE PROBLEMS INVOLVED IN PLANNING BIOLOGICAL EXPERIMENTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian
No 4, 1979 pp 66-69

[Article by V. V. Verigo, submitted 20 Jan 77]

[English abstract from source]

The paper describes certain cases of using mathematical methods in the planning of biological experiments. The paper presents an algorithm of the distribution of the experimental data based on dynamic programming. The paper discusses an application of computer-aided calculations for the formation of nomogeneous groups of experimental and control tests.

[Text] The development of biomedical research in spacecraft and specialized biological satellites has led, in a number of cases, to problems of a scientific organizational nature, and it is desirable to use the appropriate mathematical procedures to find adequate solutions. Some of the questions arising in this regard are discussed here.

One of the most important stages of research aboard specialized biosatellites is the postflight examination of animals. The latter is a complex and complicated scientific procedure that includes a large number of experiments. It must be borne in mind that at least several animals must be used in each of the experiments to assure statistical reliability. Considering that there is a possibility of a reduction in planned number of experimental animals for different reasons, it must be conceded that there is a real probability of a situation, in which there will be a disproportion between the available amount of experimental material and requirements of research programs of postflight studies. For this reason, it is deemed expedient to use an algorithm of distribution of experimental material, which takes into consideration the relative priority of some experiments, the need for a given number of animals and other factors. We shall describe below a model algorithm based on a series of simplified hypotheses.

Let the experimental material consist of a certain finite set of discrete identical objects. The number of elements n in the set may range from 1 to the maximum possible number $N = n_{max}$. The set of objects must be distributed among r types of experiments. Let there be a specified weight function for the set of types of experiments, which links with each jth type

of experiment coefficient α_j, which determines the priority of a given experimented provided a sufficient number n_j of animals is used in it. The effectiveness of this experiment apparently depends on n_j. Let us define it as $\phi_j = \alpha_j I_j$, where α_j is the above-mentioned weight coefficient and $I_j(n_j)$ is the function of informativeness. The choice of its structure will be discussed below, and here let us merely stipulate that it must satisfy conditions $I_j(0) = 0$, $\lim I_j(n) = 1$.

The problem is to select whole number values of n_{ij} in such a manner that the values of forms $\Phi_i(n^*) = \sum_{j=1}^{r} \varphi_{ij} = \sum_{j=1}^{r} \alpha_j I_j(n_{ij})$ would reach their maximum values with observance of restriction $\sum_{j=1}^{r} n_{ij} \leq n^*$, where n^* assumes values of 1 to N (index i, which equals argument n^* in the designation for the maximized form, shows the resource level at our disposal).

The formulated problem is not trivial with large enough r and N, in spite of several obvious simplified assumptions made to formulate it. The most significant of these assumptions are the hypotheses of mutual independence of functions of effectiveness of different experiments, identity of objects and use of a fixed animal in one type of experiment. To solve it, it would be the most expedient to use the method of dynamic programming proposed by R. Bellman [1]. In this problem, it amounts to solving the following functional equation

$$\Phi_j(n^*) = \max_{0 \leq n_j \leq n^*} [\varphi_j(n_j) + \Phi_{j-1}(n^* - n_j)]$$

for $j = 2, 3, \ldots r$. The value of $\Phi_1 = \phi_1$ is defined as $\Phi_1(n^*) = \alpha_1 I_1(n^*)$.

The scheme for selecting optimum values of n_j can be described as follows: Let us assume that optimum values n_j have already been found for $j_0<r$ types of experiments for all values of level of resources $1 \leq n^* < N$, and for j_0+1 types of experiments for resource levels $1 \leq n^* \leq n_0-1$. Let us assume that, at this step, one must determine optimum distribution of n_j with $j = j_0+1$ and $n^* = n_0^*$.

In this situation, we could use $a = 0, 1, 2, \ldots, n_0^*$ animals for experiment with number j_0+1. Then, we shall have n_0^*-a animals left for all preceding j_0 experiments. Therefore, it is sufficient to determine the maximum for a in the following equation: $\xi(a) = \alpha_{j_0+1} I_{j_0+1} + \Phi_{j_0}(n_0^* - a)$.

The value of a which permits maximum expression of ξ is the sought n_j with $j = j_0+1$ for the given level of resources n_0^*. The formation of corresponding cycles in running the algorithm on a computer is obvious.

A table of values of n_{ij} and $\Phi_j(n^*)$, where $1 \leqslant i \leqslant N$ and $1 \leqslant j \leqslant r$, is the result of calculation with the above algorithm. Setting n^* determines the optimum value of n_r for the rth experiment, the optimum value of n_{r-1} for the preceding $(r-1)$th experiment corresponds to a resource level of n^*-n_r, etc. Let us recall that function Φ_j is used to assess the effectiveness of the entire set of the first j experiments, rather than of the jth experiment alone.

In order to use the proposed algorithm, we must have specified coefficients α_j, the values of which can be obtained on the basis of expert estimates or another means, and functions of informativeness I_j, which are selected on the basis of consideration of adequacy of experimental material for reliable interpretation of results of the experiment. In a model test of the algorithm, we expressed functions I_j in the form of curves of the logistic type:

$$I_j(n_j) = \frac{e^{-\varepsilon_j m_j}\left(1-e^{-\varepsilon_j n_j}\right)}{e^{-\varepsilon_j m_j}+e^{-\varepsilon_j n_j}}.$$

Parameter m_j corresponds to the point on the x-axis where function I has a point of inflection. The parameter ε_j indicates the rate of change in the function. In a real situation, the functions of informativeness of experiments can be set in any form that permits constructive determination of their values, including tabulated form.

The proposed method was used as a program in the ALGOL algorithmic language [2]. As an illustration, we shall give the results of calculation in the case where $N = 45$ and $r = 10$. The values of α_j, m_j and ε_j for three variants are listed in Table 1. Table 2 lists the optimum distributions for these 3 variants with $n^* = 23$ and $n^* = 45$. As we see, most of the material is referred to experiments with high values for the priority coefficient. In the event of a shortage of material, preference is given to the experiment with the lower value of m_j. In some cases, an increase in ε_j could also cause assignment of material for an experiment.

Another task, even more important in our opinion, is the formation of as homogeneous as possible groups of animals or other biological objects for test and control experiments.

Before undertaking the formation of homogeneous groups, we must define the meaning of the concept of "homogeneity" in each concrete case. This work should begin with preparation of a list of the biological parameters for which homogeneity of groups is desirable. The animal's weight, number of formed blood elements, biochemical indices, etc., can serve as such parameters. Let us indicate that it is expedient to divide the entire set of parameters into the following three categories: a) parameters that are relatively constant over periods of time commensurate with the time of performance of the experiment; b) parameters that change substantially and

and in the same direction in time (for example, weight); c) parameters that change periodically in time.

Table 1. Values of parameters α_j, m_j and ε_j for three variants of combinations thereof

Variant	Parameter	Experiment No 1	2	3	4	5	6	7	8	9	10
1	α_j	3	3	10	10	1	5	1	1	5	3
	m_j	5	5	5	5	5	5	5	5	5	5
	ε_j	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.3
2	α_j	3	3	10	10	1	5	1	1	5	3
	m_j	5	15	5	15	2	2	15	10	10	−10
	ε_j	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.3
3	α_j	3	3	10	10	1	5	1	1	5	3
	m_j	5	5	5	5	5	5	5	10	10	10
	ε_j	0.1	1	0.1	1	0.5	0.5	0.5	1	1	1

Table 2. Optimum distributions for the three variants with $n^* = 23$ and $n^* = 45$

n^*	Variant	Experiment No 1	2	3	4	5	6	7	8	9	10
23	1	0	0	5	5	1	1	1	1	8	1
	2	0	0	16	1	1	1	1	1	1	1
	3	0	0	3	8	1	7	1	1	1	1
45	1	0	0	14	16	1	1	1	1	10	1
	2	0	0	15	12	1	1	1	1	13	1
	3	0	0	6	8	1	8	1	1	13	1

In the last two cases, it is desirable to use the rate of increase (decrease) in value of a parameter or amplitude and phase of periodic change therein as an informative index.

By virtue of natural biological variability, the selected parameters will differ in different animals. The aggregate of these values in different groups would form a certain statistical distribution. One must determine the characteristics of these distributions that one wants to be homogeneous, for example, one can form two groups with the same mean value of a given biological parameter but different variance, etc.

It is apparent from the foregoing that, in a real situation, when forming groups we shall have to consider several (if not several dozen) digital characteristics. Since we know in advance that they cannot be identical for different groups, we must specify their relative priority in order to formulate a criterion that determines which distribution of the initial set of animals into two groups is optimum from our point of view.

When distributing a selected set of animals into a specified number of groups, the number of possible combinations is quite high (for example, when distribution a set 2N of animals into 2 groups it constitutes

$$C_N^{2N} = \frac{2N!}{(N!)^2} \approx \frac{2^{2N}}{\sqrt{\pi N}},$$

which, in the case of 2N = 30 constitutes hundreds of millions of different combinations). For this reason, it is expedient to use a computer algorithm to determine the optimum distribution.

The mathematical problem could be formulated as follows: N points have been specified for a real space with dimensionality R. This set of points is divided into two (experimental and control) groups, the coordinates of points of which constitute a random vector sample. The criterion of group homogeneity is specified. For the case of two groups, it can be selected in the following form:

$$L = \sum_{i=1}^{R} \sum_{j=m_0}^{m_k} \lambda_j (M_{1ij} - M_{2ij})^2,$$

where sequence m_0, m_1 and m_2 represents k numbers of sample moments considered in forming homogeneous groups, M_{1ij} and M_{2ij} are the values of random [sample] moments and λ_j are the corresponding weight coefficients. We must devise a method of distributing the points into groups that would provide a minimum value of the criterion for the large number of possible distributions. Let us observe that this formulation is basically different from the usually considered problem of singling out from one set the points referable to different classes.

An effective method can be proposed by different means. In the case of predominance of one of the weight coefficients, it is expedient to put the points in order on a given coordinate, then divide this sequence into pairs. Points from several of the first pairs are arbitrarily distributed into groups. When distributing the points of each successive pair, all possible distributions thereof into groups are scanned and the optimum (minimum) current value of the criterion is chosen. An alternative route is the use of the procedures in the Monte Carlo method. The choice of features,

for which homogeneity is achieved, as well as the values of weight coefficients, depends on the specifics of the experiment and should be made jointly with experimenters.

The problems discussed here are an example of the problems involved in planning biological experiments, for the solution of which algorithms for computer calculations may find effective applications.

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ADAPTIVE OPTIMIZATION OF EXCHANGE OF GASES IN PLANTS IN A SEALED PHYTOTRON

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 70-73

[Article by Berkovich, V. L. Korbut and O. B. Suslova, submitted 24 Feb 77]

[English abstract from source]

The study of adaptive optimization of wheat photosynthetic productivity in the phytotron allowed a 25-100% increase in the daily volumes of carbon dioxide assimilated by plants.

[Text] At the present time it is believed that the cenoses of higher plants could constitute the main part of the autotrophic element of a biological life support system (BLSS), with regard to their share in mass exchange [1].

Energy-mass characteristics are among the important indices of refinement of construction of the higher plant element in the complex hierarchic structure of BLSS. Using a previously described method [2], one can calculate that the overall mass of the higher plant element is proportional to its biomass productivity and inversely proportional to $(K_E)^{\alpha}$, where K_E is the coefficient of utilization by plants of photosynthetically active radiation (PAR) and $\alpha > 1$. The data on plant physiology warrant the belief that parameter K_E in crops, as well as agricultural crop harvests, can be increased by several times by optimizing the technological cultivation conditions in phytotrons with controllable environmental parameters. It is preferable to implement automatic optimization of complex objects with nonstationary characteristics, which also include crops that are elements of lower levels in hierarchic structures, by means of adaptive control systems [3]. The main advantage of adaptive control is that it is possible to determine the optimum (with regard to a certain index of quality) modes for objects, for which there is no complete mathematical description and which function under changing conditions. Since the best modern mathematical models of the production process of plants can predict the current characteristics of a real planted crop only with a margin of error of the order of several tens of percentage points, they cannot be considered suitable for optimization by means of the classical methods of mathematical programming. One of the effective means of improving technological modes of plant growing in

phytotrons is to design adaptive systems of maximizing the main parameters of photosynthetic productivity of plants, such as visible photosynthesis Φ, coefficient of utilization of physiologically active radiation for photosynthesis $K_E = \Phi/E$ (where E is extent of irradiation of crop in the phytotron) and parameter $P = K_E \cdot \Phi$, which characterizes the effectiveness of gas exchange as a function of assimilating surface of plants and degree of irradiation concurrently [4].

In this article, we describe and experiment dealing with adaptive optimization of biological productivity of wheat planted in a 1 m^2 phytotron, according to the criterion of maximum current value of visible photosynthesis in the space of three most important parameters of the plant environment: degree of irradiation PAR of plants E, air temperature T and concentration of carbon dioxide C_α in the phytotron. The flowchart of the experimental unit is illustrated in Figure 1. In addition, the following parameters were stabilized in the phytotron: oxygen concentration in air C_β (20.5-21.5%), temperature of nutrient solution in the root region T_k (17-18°C), relative air humidity ϕ (70%). We adopted a substrate-free aeroponic system of cultivation with periodic soaking of the plant roots with nutrient solution. The plants were exposed to radiation around the clock from three xeonon arc lamps, type DKSTB-6000 with aqueous shield and glass filter, type SZS-24, which let through the segment of the spectrum from 450 to 680 nm.

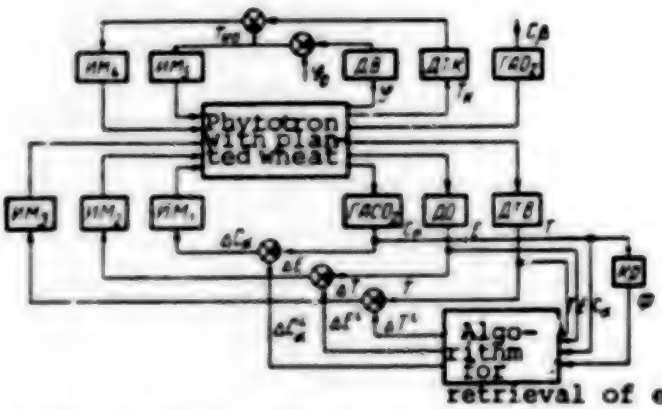

Figure 1. Flowchart of experimental unit for adaptive optimization of photosynthesis of a wheat planting

Key: ГАО$_2$) gas analyzer for oxygen
ГАСО$_2$) gas analyzer for carbon dioxide
ДТК) temperature sensor in root region
ДО) radiation sensor
ДВ) moisture sensor
ДТВ) air temperature sensor
ИМ$_1$-ИМ$_5$) actuating mechanisms of corresponding control circuits
i) step number
T_{k0}, ϕ_0) stabilized values of temperature in root region and air humidity in phytotron, respectively
K_p) unit for calculation of optimization criterion

The hypothesis of unimodal function of quality index $\Phi(E, T, C_a)$, which is confirmed by numerous data concerning unimodality of special static characteristics $\Phi(E)$, $\Phi(T)$ and $\Phi(C_a)$, made it possible to formulate the problem of retrieving the maximum according to three parameters as a problem of defining the local extremum which, in this case, coincides with the overall one. In the experiment described, a simplex algorithm of nonlinear mathematical programming was used. The above static characteristics of photosynthesis indicate that the maximum levels of photosynthesis are not on the limits of the permissible range of values of the corresponding parameters of the environment. For this reason, in this experiment, we solved the problem of unconditional maximization of photosynthesis in the three-dimensional space of the parameters.

For the sake of convenience of operator work, who sets the steps--search changes in environmental factors in accordance with the algorithm--a special panel was made, which was described previously [5]. The operator, who compared measu[illegible] photosynthesis after different steps, moved plugs in accordance with a simple scheme and thus determined the next values of the steps.

The size of the steps [pitch?] for environment parameters, as well as periodicity of mode change, are the most important characteristics of the simplex algorithm. A series of experiments was conducted to define these characteristics, with measurement of transitory processes of photosynthesis of a wheat crop with step changes in specified values of parameters. As a result, it was found that maximum duration of transitory processes with steps of set values--$\Delta E \leqslant 20$ W/m^2, $\Delta T \leqslant 4$°C, $\Delta C \leqslant 0.04$%--does not exceed 20 min, in both the direction of increase and decrease, in the range of 40 W/m$^2 \leqslant E \leqslant$ 450 W/m^2 12°C$\leqslant T \leqslant$40°C 0.07% $C_a \leqslant$0.41%. It was established that it is virtually impossible to determine, from the appearance of the initial segment of the transitory process (for example, according to rate of change), which of the established levels of photosynthesis will be present after termination of the transitory process; bearing this in mind, the discreteness of measuring photosynthesis in the course of optimization constituted at least 20 min, and the steps did not exceed the indicated values. The wheat crop in the phytotron was submitted to optimization of photosynthesis starting at the age of 22 days, once a week, throughout the vegetation period. The duration of each optimization session constituted 1 to 2.5 days. After obtaining values for E, T and C_a corresponding to maximum photosynthesis, these values were fixed up to the next optimization session.

The main results of this experiment were as follows: Periodic adaptive optimization by means of a simplex algorithm made it possible to track the drift of extremum of photosynthesis of the wheat crop in ontogenesis. Figure 2 illustrates the dynamics of photosynthesis over the vegetation period. The averaged curve in Figure 2 is similar in shape to the course of photosynthesis under "factorostatic" [?] conditions, determined by the ontogenetic changes in plant metabolism; however, a scrutiny of daily photosynthesis shows that the relative increments of rate of uptake by plants of carbon dioxide constitute 25 to 100% on the days of optimization (see Table). Thus, the rate of increase in photosynthesis during optimization sessions is

considerably higher than the mean rates of increase in photosynthesis in the intervals between these sessions, on the ascending arm of the curve reflecting the dynamics of photosynthesis. This is indicative of effectiveness of the adopted optimization algorithm.

Increment of wheat plant photosynthesis as a result of optimization of parameters of plant environment

Age of plant before optimization days	Photosynthesis before optimization (Φ_1), ℓ/day	Photosynth. after optimization, (Φ_2), ℓ/day	$\Phi_2 - \Phi_1$, ℓ/day	$\frac{\Phi_2 - \Phi_1}{\Phi_1}$, %
22	10,10	20,08	9,98	99,0
28	18,00	25,44	7,44	41,3
36	17,78	35,56	17,78	100,0
42	32,73	43,84	22,11	34,0
57	27,00	33,78	6,78	25,1

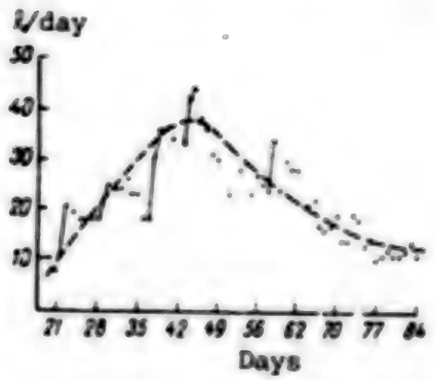

Figure 2.
Dynamics of photosynthesis of wheat crop during the period of vegetation

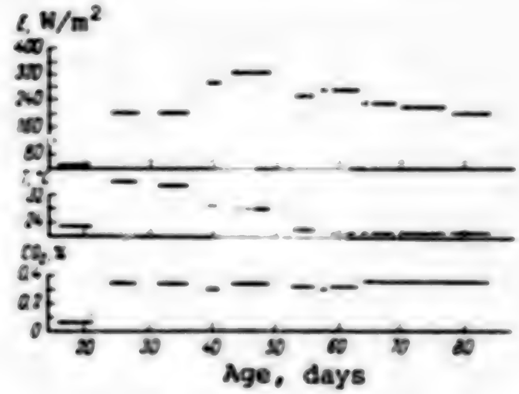

Figure 3.
Change in optimum environment parameters in phytotron as a function of plant age

The optimum modes determined during the optimization sessions changed substantially, depending on the age of the plants (Figure 3). While the concentration of carbon dioxide changed relatively little during vegetation, the scatter of optimum levels of irradiation E constituted 120 W/m² PAR, i.e., about 60% of the initial level; the scatter of optimum temperatures T constituted 18°C, which is 50% of the end value. Typically enough, the maximum of optimum temperatures was referable to the period when the rate of increase in photosynthesis in ontogenesis was at a maximum, whereas there was a significant drop of optimum temperature (to 18°C) at the time of flowering and grain formation, and it held at this level until the grain ripened.

Several physiological distinctions were noted in the plants during the sessions of optimization of photosynthesis, which affect the process of searching for optimum modes. After long-term exposure to "factorostatic" conditions, low "steps" of parameters, in both the direction of increase and decrease, did not lead to an increase in photosynthesis; however, there was such an increase with several steps in a specific direction. Moreover, in some cases there was establishment of an algorithm cycle about a fixed point, in spite of drift of the extremum point, after bringing out the working point in the three-dimensional space of parameters to the optimum region. Evidently, such effects can be attributed either to the presence of relatively high-frequency components in the extremum drif, the rate of which is commensurate with the rate of convergence of the described algorithm, or presence of an internal homeostatic regulator, which alters the reactions of the plant to step factors referable to environmental parameters during the optimization process.

This experiment demonstrated the efficiency of the developed system of adaptive optimization of photosynthesis of plants cultivated in a sealed phytotron. With appropriate choice of optimization criteria, such systems of adaptive control could automatically provide for better energy-mass characteristics of the higher plant element of BLSS than under any "factorostatic" conditions, by means of increasing K_E and specific productivity of agricultural crops.

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QUALITY OF WATER RECLAIMED FROM URINE AS RELATED TO pH OF INITIAL PRODUCT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 73-76

[Article by N. M. Nazarov, I. V. Yakimova, N. A. Golikova, Yu. Ye. Sinyak and S. V. Chizhov, submitted 28 Dec 76]

[English abstract from source]

It has been demonstrated that the quality of reclaimed water depends on pH of initial urine: the water reclaimed by evaporation at temperatures not higher than 50°C shows higher content of ammonium nitrogen and better oxygenation at pH 3—5.

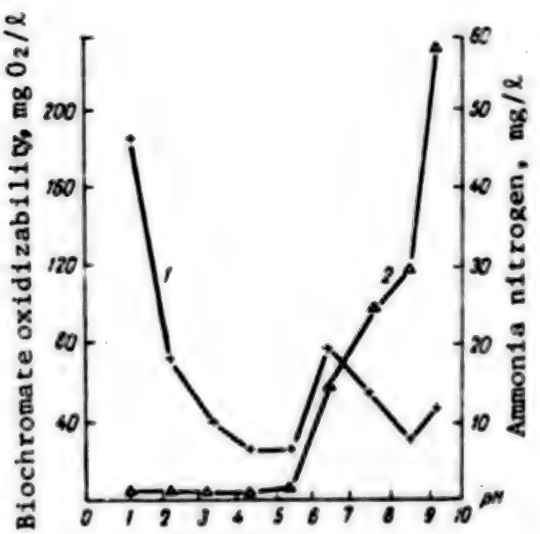
[Text] In the course of long-term space flights, it becomes necessary to create a system for reclaiming water from water-containing human waste. The latter includes such a chemically complex mixture as urine. On the order of 300 volatile compounds have been found in the urine of healthy individuals, among which ketones, alcohols, lactones, terpenes, etc., have been identified [1]. Urine also contains ammonia in the form of ammonia salts (chlorides, sulfates, phosphates) [2, 3]. The 24-h amount thereof ranges from 0.4 to 1.2 g [3]. Many components of urine and, first of all, volatile ones, may get into the reclaimed water and render it unfit for consumption. Pretreatment of urine (preservation) improves substantially the physicochemical and organoleptic qualities of reclaimed water [4, 5]. Various chemicals, which may include acids, are used as urine preservatives in water-reclaiming systems [5]. The acid may have a dual effect on the chemical components of urine. On the one hand, the preservative may improve the quality of reclaimed water as a result, let us say, of binding of ammonia in a stable complex; on the other hand, it can cause formation of new compounds as a result of decomposition of urine components which worsen the chemical parameters of reclaimed water. For these reasons, it was deemed interesting to determine the correlation between quality of reclaimed water and initial pH of urine.

Methods

Water was extracted from urine by evaporation in a stream of air at a temperature not exceeding 50°C. Urine was treated with sulfuric acid and caustic soda. The pH of urine and reclaimed water was measured with an LPU-01 laboratory pH-meter. The colorimetric method was used to assay urea [6] in urine, as well as ammonia and nitrite nitrogen. The reclaimed water was submitted to chemical analysis for determination of its active reaction, oxidizability with potassium permanganate and bichromate [7]. It must be noted that urine remained decontaminated during the experiment (6-7 h), so that all of the changes in parameters of quality of reclaimed water can be related to chemical conversions of urine components after treatment thereof.

Results and Discussion

The obtained experimental data indicate that different pH levels can have a substantial effect on the quality of reclaimed water, without altering the level of bichromate oxidizability (~20,000 mg O_2/ℓ) and ammonia nitrogen (~1000 mg/ℓ) of urine.



Level of bichromate oxid (1) and ammonia nitrogen (2) as a function of initial pH of urine

The Figure illustrates bichromate oxidizability of reclaimed water and its ammonia nitrogen content as a function of pH of urine. Bichromate oxidizability makes it possible to make an overall estimate (90-95%) of the levels in water of organic admixtures that are so abundant in the base product. The Figure shows that there is an inverse correlation between levels of bichromate oxidizability and ammonia nitrogen of reclaimed water at some values of urine pH. Bichromate oxidizability of water decreases when initial urine pH drops from 6 to 5. In the pH range of 3 to 5, bichromate oxidizability presents minimum values, and it increases drastically

with urine pH of less than 3. The findings are different with regard to ammonia content of reclaimed water: decrease in level thereof with decrease in initial pH of urine, and increase with increase in urine pH.

Indices of quality of reclaimed water as related to initial urine pH

Urine pH	H_2SO_4, g/ℓ	NaOH, g/ℓ	Indices of quality of reclaimed water: pH	permanganate oxidizability, O_2 mg/ℓ	nitrite nitrogen, mg/ℓ	ammonia nitrogen, mg/ℓ
1	41,5		3,53	55,5	0,09	0,00
2	6,7		3,24	31,6	0,08	0,00
3	3,8		3,14	15	0,13	0,00
4	2,2		3,57	10,3	0,05	0,00
5	1,4		3,97	6,7	0,05	0,5
6*			7,7	11,5	0,06	16
7		0,27	8,25	8,6	0,08	24
8		0,65	7,76	7,9	0,07	26
9		1,37	8,56	9,9	0,07	58

*Urine without reagent treatment.

It should be noted that urine is a buffer mixture, and a rather large amount of acid must be added to lower its pH from 6 to 1. The Table lists the amounts of sulfuric acid and caustic soda that must be added to alter an initial urine pH of 6. The same table lists the indices of quality of reclaimed water (pH, permanganate oxidizability, nitrite and ammonia nitrogen) as related to urine pH. As we see, initial urine pH influences the level of permanganate oxidizability and nitrite nitrogen. As in the case of bichromate oxidizability, permanganate oxidizability increases with decrease in initial urine pH and decreases somewhat at pH>6. There is a 50% increase in nitrite nitrogen in reclaimed water with urine pH in the range of 1-3 and 25% increase with pH 7-9. In all of the tests, the urea level remained constant, and it constituted 13-15 g/ℓ.

According to the obtained results, the quality of reclaimed water depends on the active reaction of treated [processed] urine. Water recovered without reagent treatment of urine contains 16 times more ammonia nitrogen than at low pH levels. In the case of alkaline urine (pH 9), the amount of ammonia nitrogen in reclaimed water increases by almost 4 times. Bichromate oxidizability of water is at a minimum with initial urine pH of 3 to 5, whereas at pH 1 bichromate oxidizability even exceeds oxidizability of water recovered from untreated urine by more than double; at pH 7-8, bichromate oxidizability is almost one-half the control level. It was previously noted that ammonia is present in urine in the form of salts (ammonia chloride, ammonia carbonate, ammonia phosphate, etc.), which are unstable and can separate [decompose] with discharge of ammonia. In untreated urine, first of all there is dissociation of ammonia salts to ammonia, but not of urea, since the level thereof remained constant throughout the experiment.

The increase in ammonia nitrogen content in an alkaline medium can be attributed to formation of a labile compound from ammonia salts, ammonia hydroxide, subsequent release of ammonia in the gas phase and dissolution in a condensate. When sulfuric acid is added to urine, there is formation of a stable ammonia sulfate salt, and no ammonia is released into the gas phase.

However, the recovered water cannot be used for drinking purposes without additional purification. The question arises as to what kind of water is desirable: with low ammonia content but high oxidizability or, on the contrary, with high ammonia content and low oxidizability. This question can be answered on the basis of data pertaining to exchange capacity of exchangers that absorb ammonia and adsorption capacity of carbons with respect to organic substances. Data in the literature warrant the conclusion that it is simpler to bring reclaimed water with high ammonia content to a potable quality than it is to do so with water with low ammonia content but high oxidizability. The most effective are, for example, the KU-2×16 cation exchangers in the Si [?] form, the total exchange capacity of which for ammonia constitutes 3.35 mg-eq/ℓ [5]. It is more difficult, however, to remove organic impurities from reclaimed water. This is attributable primarily to the lack of data on sorption capacity of carbons with regard to the different components of urine that remain in water in the course of reclamation.

On the basis of the obtained experimental data, it can be concluded that the quality of reclaimed water depends on the pH of initial urine: water reclaimed from urine by evaporation has better chemical parameters, according to ammonia nitrogen content and oxidizability, with initial urine pH of 3-5.

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UDC: 574.685

EVALUATION OF OXIDIZABILITY OF AIR IN CLOSED AREAS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 76-78

[Article by L. A. Mokhov, L. D. Karpova and N. Ya. Shuinova, submitted 24 Jan 77]

[Text] Oxidizability [oxygenation?] is one of the indices of sanitary and hygienic state of air in work areas, as it permits approximate determination of levels of volatile organic substances.

Acetic acid, aldehydees, as well as a number of other organic substances, are the natural products of human vital functions, and they are released into the environment with exhaled air, sweat, urine, excrements, etc. In the air of a small, closed area, these organic compounds as a whole could induce discomfort, associated with a number of unpleasant sensations (odor, nausea, vertigo, headache, etc.). Heretofore, air "oxidability" has been determined according to the organic impurities capable of oxidation to acetic acid or acetaldehyde, and as a result a number of compounds are overlooked. For this reason, when making a sanitary chemical evaluation of air in closed areas of a limited size, one must oxidize, if possible, organic impurities to carbon dioxide [1-4].

In this work, we tested the influence of duration of reaction, acidity of medium, heating conditions and use of catalysts on the reaction of oxidation of ethanol.

Methods

The bichromate and standard (CEMA) methods were used as the basis for determining oxidability of water [5]. As the standard, we used an aqueous solution of ethyl alcohol containing 100 mg alcohol per liter solution.

We proceeded from the following calculations in assessing the results of the studies: Depending on the conditions, under which the analysis is performed, ethyl alcohol can be oxidized to acetaldehyde, acetic acid or carbon dioxide:

$$C_2H_5OH + {}^1/_2O_2 \longrightarrow CH_3COH + H_2O \qquad (1)$$

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O \qquad (2)$$

$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O \qquad (3)$$

According to stoichiometric calculations using these equations, oxidability of samples containing 100 mg ethanol should constitute 34.7, 69.4 and 208.2 mg O_2, respectively. A comparison of the estimated data to experimental data enables us to determine the degree of oxidation of ethanol and assumed reaction products.

Preliminary experiments established that oxidation of ethanol was virtually complete within 30 min of boiling samples, both in a water bath and in flasks with a reflux condenser. Longer heating did not cause substantial changes in the direction of increased oxidizability, so that all samples were subsequently heated for 30 min.

The standard method, which was modified in the course of the studies, consisted of the following: Into two successively connected Polezhayev absorbers we decanted 5 mℓ chromium mixture (0.5 N $K_2Cr_2O_7$ in concentrated H_2SO_4, specific mass 1.84). Using a blower, 5 ℓ of the tested air was pumped through the absorbers at the rate of 0.1-0.15 ℓ/min. After blowing the tested air through, 150-200 mg silver sulfate was added to the absorbers with the chromium mixture and to a control sample, then they were shaken and submerged in a boiling water bath for 30 min. The sample was periodically shaken until the silver was completely dissolved. After cooling, the contents of the absorbers were transferred to different flasks for titration; the volume of wash water was brought up to 40 mℓ and the samples were again cooled in cold water. Just before titration, we added 3 drops of indicator--phenylanthran lic acid--into the flas, and after 20-30 s we titrated with 0.05 N Mohr's salt until the reddish-blue color changed to bluish-green, which was the final point of titration.

Calculation of oxidizability was made using the following equation:

$$C = \frac{(a - b) \cdot K \cdot 0,4 \cdot 1000}{V},$$

where C is the amount of O_2 required for oxidation of organic substances (in mg O_2/ℓ), a is the amount of 0.05 N Mohr's salt used to titrate the control sample (mℓ), b is the amount of 0.05 N Mohr's salt used to titrate the experimental sample (mℓ), K is the correction coefficient for Mohr's salt solution, 0.4 is the conversion factor (amount of oxygen corresponding to

1 mℓ 0.05 N Mohr's salt) and V is the volume of passed air, scaled to normal conditions (in m³).

The following is required to conduct the tests: 1) 0.05 N $K_2Cr_2O_7$ (GOST 4220-48) in concentrated H_2SO_4 (specific mass 1.84); 2) 0.05 N Mohr's salt (GOST 4208-48); 3) crystaline silver sulfate for analysis (GOST 1277-4); 4) phenylanthranilic acid (TU [technical specifications] of the Ministry of the Chemical Industry 2875-51); 5) Polezhayev absorbers; 6) 150-200 mℓ flasks for titration; 7) graduated 5 mℓ pipettes; 8) graduated 50 mℓ cylinder.

Results and Discussion

The ethanol samples underwent oxidation by the bichromate method only to acetic acid. Thus, according to reaction equation (2), 69.4 mg O_2 is required to oxidize a sample containing 100 mg/ℓ ethanol, whereas experimentally we obtained 71.9±1.2 and 71.6±2.8 mg O_2.

In the former case, the samples were boiled in a water bath in concentrated sulfuric acid and in the latter case, in a flask with reflux condenser in 50% sulfuric acid. Boiling the samples in flasks with reflux condenser in concentrated sulfuric acid led to separation of bichromate and acid.

The use of the modified standard method (CEMA) with a silver sulfate catalyst made it possible to oxidize ethanol virtually to carbon dioxide. An average of 201.2±4.1 mg O_2 is used to oxidize 100 mg ethanol, whereas the figure is 208.2 mg O_2 according to the stoichiometric equation (3). Thus, use of silver sulfate as a catalyst yields 96.6% oxidation of ethyl alcohol to carbon dioxide.

In subsequent studies to determine oxidizability of volatile organic substances in air, we used a modification of the CEMA method, which demonstrated the best results for oxidation of aqueous solutions of ethanol.

Determination of "oxidizability" of the air of work rooms of a limited size by the bichromate method with concentrated H_2SO_4 and modified CEMA method revealed that "oxidizability" of air was 28% higher in the latter case.

Since the method of bichromate oxidizability with the use of catalysts (silver sulfate) yields oxidation of ethanol to carbon dioxide, it is possible to provide a more complete evaluation of the degree of air pollution by volatile organic compounds in closed areas of a limited size.

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BRIEF REPORTS

UDC: 612.766.2.014.41

EFFECT OF HYDROSTATIC FACTOR ON ORTHOSTATIC STABILITY AND PHYSICAL FITNESS OF MAN DURING 60-DAY ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 78-80

[Article by O. D. Anashkin, Z. K. Trushinskiy, F.V. Reva and T. P. Shatunina, submitted 10 Nov 77]

[Text] The question of the role of the hydrostatic factor as a means of preserving orthostatic stability with hypokinesia remains open. Some authors observed a positive hydrostatic influence on orthostatic stability during 18-h hypokinesia [1], while others, on the contrary, observed that the presence of hydrostatic pressure does not have a positive effect on orthostatic stability when muscular activity is restircted [2].

Our objective here was to investigate the influence of the hydrostatic factor on orthostatic tolerance and physical fitness of man in the course of long-term antiorthostatic [head-down] hypokinesia.

Methods

Six essentially healthy male volunteers participated in the studies; they ranged in age from 19 to 37 years, and they were selected after an in-depth clinical and physiological work-up. At all stages of the studies, they consumed natural food totaling about 3000 kcal/day. Fluid intake was not restricted. Three subjects, who made up the control group, were kept on strict bed rest in antiorthostatic position, with the head end of the bed tilted -4.5° down, for 60 days. The other 3 subjects spent 2 h per day in sitting position (1 h after breakfast and 1 h after lunch [or after lunch and dinner--terms are ambiguous]), and the remaining 22 h they were in strict antiorthostatic position, like the subjects in the control group. For each 1-h hydrostatic session, they sat in bed for 45 min with the legs extended horizontally and 15 min, with the legs dropped. A 20-min passive orthostatic test (75°) was made twice in the background study, then on the 11th, 18th, 25th, 32d, 39th, 46th, 52d days of hypokinesia and on the 1st day of the recovery period. The heart rate was recorded continuously and

Table 1. Maximum heart rate and arterial pressure during orthostatic test in vertical position ($\bar{X}\pm m$)

Parameter	Group	Background	Day of hypokinesia							1st day of recovery
			11	18	25	32	39	46	53	
Heart rate per min	Control	97±1,3	111*±2,6	115*±2,4	102±2,8	116*±1,2	115*±3,3	116*±1,9	112*±2,1	127*±2,4
	Hydrostat.	96±0	101*±1,3	109*±1,5	108*±1,9	115*±2,8	120*±3,0	141*±1,9	124*±1,9	119*±3,2
Systolic arterial pressure, mm Hg	Control	102±3,2	121*±2,8	115±2,4	123*±1,8	123*±3,1	110±3,8	126*±3,4	125*±3,2	121*±2,4
	Hydrostat.	106±3,2	120±4,7	112±3,9	118*±1,4	112±3,8	118*±2,4	115*±3,8	112±1,9	118*±2,3
Diastolic arterial pressure, mm Hg	Control	78±2,1	91*±1,7	90*±3,8	91*±2,1	91*±2,5	88*±1,2	95*±3,8	[illegible]±2,6	88*±1,7
	Hydrostat.	83±2,5	100*±1,0	98*±3,2	96*±2,0	91±2,1	96*±2,0	96*±2,0	86±1,7	86±3,2
Pulsed arterial pressure, mm Hg	Control	30±1,7	30±1,5	25±1,7	32±1,1	32±1,7	22*±0,9	31±2,4	39*±2,4	33±0,8
	Hydrostat.	23±1,2	20±2,1	14*±1,4	22±0,9	21±1,7	22±0,9	19*±0,7	27*±0,8	32*±1,7

*Results are statistically reliable, $P<0.05$.

arterial pressure, by the method of Korotkov. Physical fitness was evaluated by the PWC-170 test [3], which was performed 2 h after breakfast [or lunch] on the same days as the orthostatic test. It is known that a heart rate of 170/min characterizes the start of the range of optimum function of the cardiorespiratory system with a load [3].

Results and Discussion

All of the subjects tolerated the orthostatic test well before hypokinesia. During hypokinesia, all of them observed an appreciable decline of orthostatic stability, with a reliable increase, as compared to the background, in heart rate when in upright position (Table 1). Orthostatic collapse was observed on the 11th and 54th days of hypokinesia in 1 subject submitted to the hydrostatic factor. As can be seen in Table 1, the hydrostatic factor used during antiorthostatic hypokinesia did not have any beneficial effect on orthostatic stability.

By the end of the period of hypokinesia, physical fitness diminished by a mean of 33% in the control group and 34% in the group where the hydrostatic factor was used. A decrease in physical fitness [capacity] was observed in all 6 subjects, starting on the 11th day of hypokinesia (Table 2). The obtained results indicate that the hydrostatic factor has virtually no effect on physical fitness of man during hypokinesia.

It is known that there is deterioration of orthostatic stability and physical fitness of man when muscular activity is restricted [4-6]. It may be assumed that exposure to the hydrostatic factor for 2 h would have the same beneficial effect on

orthostasis as obtained by applying negative pressure to the lower half of the body. However, a beneficial effect can probably be obtained only when variable negative pressure is used, which causes blood to shift to the lower part of the body [7].

Table 2. Physical work capacity (PWC 170 kg-m/min) during anti-orthostatic hypokinesia

Group	Back-ground	Day of hypokinesia							1st day of recovery
		11	18	25	32	39	46	52	
Control	1136 ± 114	956 ± 130	933 ± 161	860 ± 55	880 ± 41	890 ± 54	806 ± 54	800 ± 69	760 ± 85
Hydrostatic factor	1256 ± 61	1100 ± 100	1100 ± 57	1076 ± 113	1043 ± 47	1066 ± 65	1030 ± 45	1023 ± 91	893 ± 128

Thus, daily use of the hydrostatic factor for 2 h during 60 days of hypokinesia did not have a beneficial effect on man's orthostatic stability and physical work capacity.

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UDC: 612.886.1-06:612.766.2

VERTICAL ORIENTATION OF MAN DURING 5-DAY ANTIORTHOSTATIC HYPOKINESIA (-4, -8 and -12° HEAD DOWN POSITION)

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 80-83

[Article by B. B. Bokhov and Yu. N. Taranenko, submitted 19 Jul 77]

[Text] It is known that the visual and gravity receptors are involved in man's orientation in relation to the physical vertical plane, regardless of his position in space. The presence of a vertical constant makes it possible to correctly estimate the true geometric relations in space and to plan accurately actions with surrounding objects. Under ordinary conditions, man prefers to use the visual vertical constant, because mistakes are often made in identifying the vertical line when the field of vision is inclined [1, 2]. They are manifested by shifting the subjective vertical line in the direction of inclination of optical lines (in such cases, the body seems to be tilted in the opposite direction). This result is indicative of the subordinate role of afferentation of gravity receptors, which objectively reflect the position of the physical vertical line in relation to visual afferentation, upon which the ultimate erroneous estimate is based. This phenomenon has been used in various studies as a critical test ("rod-frame" test) for demonstration of individual sensitivity of man to inclination of the visual field [3]. An illuminated frame was used as the visual field and an illuminated line or rod, as the movable [orientable] object. Individuals who presented a distinct preference for oreintation according to visual coordinates were classified as "field-dependent," and those who did not present such a capacity (i.e., who preferred to be oriented on the basis of vestibuloproprioceptive perceptions) were labeled "field-independent" [4].

In the dark, with the body straight, man's vertical orientation undergoes virtually no change, but it diminishes substantially when the body is tilted. Thus, the error is of the order of 30-40° in determining the vertical line in the dark, with the subject's body in horizontal position [5, 6]. If the body is deflected, for example, to the left of the physical vertical line in the darkness and the subjective vertical shifts to the left, it means that the subject underestimated the inclination, since the angle between the body axis and subjective vertical would be smaller than the

If, however, under the same conditions the subjective vertical is deflected to the right of the physical vertical, it means that the subject overestimated the angle of inclination of his body.

In previous studies conducted after hypokinesia, an increase in error of orientation was observed in the dark [7]. Since the tests were made in darkness, the obtained data reflected primarily changes in the gravireceptor system.

In view of the foregoing, it was planned to use two tests to study the effect of 5-day hypokinesia on vestibuloproprioceptive orientation: orientation in a field of vision without a reference point and in a field with an image ("rod-frame" test).

Methods

The methods used to test orientation against the background of a field with no reference points (test 1) were described comprehensively previously [8]. The subject made three attempts to orientate an illuminated line, which the researcher put in a different initial position each time, at angles of 30-40° to the right or left of the physical vertical. The study lasted 3-4 min.

Study of orientation against the background of a field of vision containing an image (test 2) involved the use of a rod attached in front of the image, which the researcher first placed in one of the initial positions at angles of 30, 26, 22, 18, 0 and -30° in relation to the vertical line. The direction of shift of the image toward the subject's head was designated by positive numbers. Upon delivery of a signal, in the form of lighting the image, the subject placed the rod in a vertical position by turning a ring attached to the external surface of a tube. The magnitude of error was determined from a scale on the surface of the tube. The subject made three attempts to position [orient] the rod against the background of each new position of the image. Test 2 required 20-25 min.

Four groups were formed of the eight healthy subjects, ranging in age from 27 to 37 years, each of whom participated twice in this study; the groups were formed on the basis of the subject's body position during hypokinesia. The first group was in horizontal position, the second, third and fourth had the head end of the bed tilted at angles of -4, -8 and -12°, respectively. The first and third groups, as well as the second and fourth groups, consisted of the same subjects involved at different times.

Each group was examined in the base period (twice), during hypokinesia (once a day) and in the recovery period (1st and 2d days). Tests 1 and 2 were performed in the same position that the subject occupied during hypokinesia ("main position"). In addition, all subjects were tested in horizontal position before and after hypokinesia. Testing was conducted in the main position only on the left side. When tested in horizontal position, the subjects were either on their right or left side.

Comparative rating of error of perception of gravity vertical in tests No 1 and No 2 in subjects of 1st-4th groups after 5-day hypokinesia at angles of 0, -4, -8 and -12° in relation to the horizontal

Group of subjects	Comparison of data obtained with different tests											
	before and after hypokinesia				1st & 2d day of recovery period				on left and right side, in horizontal position			
	main posit.		horizontal posit.		main position		horizontal pos.		before hypokinesia		after hypokinesia	
	test 1	test 2	test 1	test 2	test 1	test 2	test 1	test 2	1	2	test 1	test 2
1	—	—	—	—	—	—	—	Decrease ($P>99\%$)	—	—	—	—
2	—	—	Increase ($P>95\%$)	Increase ($P>99\%$)	—	—	—	Decrease ($P>95\%$)	—	—	—	—
3	—	Increase ($P>95\%$)	— ($P>90\%$)	Increase ($P>95\%$)	—	Decrease ($P>99\%$)	—	—	—	—	—	Left > right ($P>95\%$)
4	Decrease ($P>95\%$)	—	—	—	—	—	—	Decrease ($P>99\%$)	—	—	Left > right ($P>99\%$)	Left > right ($P>99\%$)

Results and Discussion

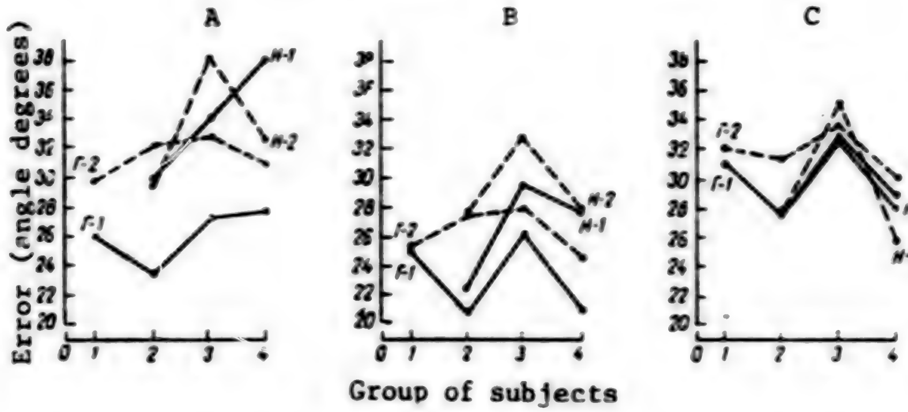
Testing of orientation during hypokinesia failed to demonstrate specific changes. Analysis of the effect of hypokinesia on orientation was made on the basis of comparison of the findings made before and after the tests.

A comparison of the data obtained in the main position before and after hypokinesia (see Figure, variant A, curves H_1-H_2) revealed that the mistakes of subjects in the 2d and 3d groups in test No 1 did not change. In test 2, a reliable change in the form of an increased error with underestimation of the angle was noted in the 3d group. A reliable decrease in mistakes after hypokinesia was found in the 4th group of subjects, according to test 1 (see Figure and Table).

The results of testing in horizontal position reflected changes in error from the main position (-4, -8, -12°) in which the subjects were submitted to 5-day hypokinesia to the new (horizontal) position. The most marked shift [change] was noted in the 2d group according to tests 1 and 2, when we compared data obtained before and after hypokinesia in this position; lesser changes were noted in the 3d group. In the 4th group there were no statistically reliable changes. Thus, maximum changes in horizontal position were demonstrated in the 2d group (with smallest angle of deflection from the horizontal line) and in the main position, in the 4th group (with maximum deflection of angle from the horizontal line).

As we have already indicated, tests 1 and 2 in horizontal position were conducted on the left and right sides. A comparison of these data revealed asymmetry in the 3d (test 2)

and 4th (tests 1 and 2) groups (see Table), which is apparently indicative of left-sided increase in tonus of skeletal muscles.



Change in vertical orientation after 5-day hypokinesia, subjects tested in recumbent position on left side: white circles, data obtained before hypokinesia and black circles, after hypokinesia

Γ-1, Γ-2) subjects tested in horizontal position
H-1, H-2) subjects in 2d, 3d and 4th groups tested in positions with angles of -4, -8 and -12°, respectively
A) orientation in field of vision without reference points
B) against the background of a straight (0°) image
C) against the background of tilted (30°) image

The stability of changes induced by hypokinesia was evaluated by comparing the results obtained on the 1st and 2d days of the recovery period. A reliable decrease in errors made was found on the 2d day in the 1st, 2d and 4th groups with the subjects in horizontal position, and in the 3d group when they were tested in the main position (see Table). It must be noted that this reduction of errors in the 2d and 3d groups actually was normalization of the change induced by hypokinesia (see Table). In the 4th group, no normalization of errors previously demonstrated in the main position was noted.

Analysis of the data listed in the Table shows that test No 2 may be the only indicator of changes in vestibuloproprioceptive vertical orientation, which occur during hypokinesia. Apparently, the greater the discoordination between afferentation of vestibular and articulocutaneous analyzers induced by stasis of blood in soft tissues [2], the greater man's sensitivity to inclination of the field of vision.

In previous studies involving antiorthostatic hypokinesia, it was demonstrated that there is a correlation between the angle of inclination of the body and orientation rror [2]. However, it must be borne in mind that

the tests were conducted in horizontal position in these studies. In the studies with 5-day hypokinesia, the subjects were tested in both tilted and horizontal position. In tilted ("main") position, hypokinesia with the largest inclination angle led to a decrease in orientation errors. However, this result alone does not reflect the full picture of orientation changes. One must take into consideration not only the absolute error increment after hypokinesia, but appearance of right and left asymmetry, as well as stability of demonstrated changes. From this point of view, antiorthostatic hypokinesia with tilt angles of -8 and -12° had the strongest effect on vertical orientation.

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EFFECT OF IMPACT ACCELERATIONS ON CHEMICAL RESISTANCE OF RAT ERYTHROCYTES

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 83-85

[Article by Ye. Ye. Simonov, submitted 26 Oct 78]

[Text] There are only isolated reports, in the literature dealing with the search for clearcut criteria of the deleterious (pathological) effect of impact accelerations on the body, that discuss attempts at using changes in different hematological parameters for this purpose [1, 2]. Our objective here was to assess the possibility of using changes in chemical (acid) resistance of erytrhocytes as such criteria.

Methods

Experiments were conducted on 36 male albino rats weighing 150-180 g, which were divided into three equal groups. The 1st group was exposed to landing impact accelerations of 410±50 units at a collision rate of 10 m/s; the 2d group was exposed to accelerations of 760±50 units at the same collision rate. Impact accelerations were produced on an SUP-10 vertical stand [3, 4]. The accelerations were in the "back--chest" direction. Blood was taken for tests from the tail before the experiment, then 1, 2 and 3 days after it. Chemical resistance of erythrocytes was determined by a modified [5] method of acid erythrograms [6]. Concurrently, determination was made of total erythrocyte count and hemoglobin content thereof.

Results and Discussion

As shown in preliminary experiments [4], the above accelerations did not induce any deviations in general condition and behavior, or visible lesions to internal organs in the first group of rats. In the second group, aggressiveness and increased motor activity appeared as a result of exposure to accelerations, which was evaluated as development of the erectile phase of traumatic shock. Postmortem examination revealed damage to lung tissue in most such animals, in the form of fine hematomas. In the third group, the condition and behavior of the animals (adynamia, paresis of hind legs, lack of reaction to sonic stimuli, etc.) were indicative of development of the torpid phase of traumatic shock. Postmortem revealed numerous

hemorrhages in thoracic and abdominal organs, soft tissues, skin, subcutaneous tissue and muscles. In some cases, the animals died within the first few minutes after exposure.

Accordingly, the rats in the first group were considered as an active control, which enabled us to assess nonspecific (stress) reactions to stimuli, which occurred in the course of preparing for and conducting the experiment (transportation, immobilization to the stand platform, a factor known not to be harmful). The animals in the second and third groups were qualified as biological models of mild and severe trauma, respectively. In view of the distinctions of these biological models, the last two of which were characterized by definite impairment of homeostasis, as well as some loss of circulating blood, we were justified in expecting qualitative and quantitative changes referable to the cellular system, with which we were concerned. However, as can be seen in the Table, we failed to demonstrate quantitative changes in erythrocytes after exposure to impact accelerations in any of the experimental groups. Hemoglobin content only changed in the third group of animals. Hence, in the case of severe trauma, a certain amount of hemoglobin was lost and this, in turn, could only have occurred in the presence of qualitative changes in erythrocyte structure, for example impaired permeability of cell membranes. In the first group of animals, the hemolysis curves after the experiment did not differ from the initial ones. Consequently, the set of factors involved in the course of preparing for and conducting the experiment, including the effect of landing impact accelerations of the indicated intensity, did not have an appreciable effect on qualitative state (chemical resistance) of erythrocytes in this experiment. In the case of exposure to landing accelerations that induced mild trauma, there were no drastic changes in nature of the acid erythrocgrams; in this case, the hemolysis curves differed little from the initial ones. Only some increase (after 24 h) in percentage of erythrocytes, hemolysis of which occurred in the interval between 3.5 and 6 min ($P = 0.05$-0.001), merited attention; it could be evaluated as an indication of increase in relative number of cells with increased resistance to acid hemolysis. This circumstance indicates that, under the conditions in question, there is some qualitative change in erythrocytes, although it is present for a brief time only. In view of the data in the literature, it may be assumed that these changes are related to hormonal influences on erythrocyte membranes [7]. A comparison of erythrograms of the third group of animals revealed that the hemolysis curves after exposure to impact accelerations are shifted to the left, as compared to the initial findings, with a steep elevation after 2 min, maximum elevation (to 25% on the 1st and 2d days) after 3 min ($P = 0.01$-0.001) and decline (to 5%) after 4-5 min. We were impressed as well by the fact that this change persisted throughout the observation period (3 days), thereby indicating the stability of changes in acid resistance of erythrocytes in the presence of severe trauma. Since the distribution of erythrocytes according to their resistance to acid depends on the age of the cells (and, as we know, young cells are highly stable, and they are situated on the right side of the graph [6, 8], it may be concluded that the increase in percentage of cells with diminished resistance to acid hemolysis is

attributable to an increase in share of "old" erythrocytes, ready to disintegrate. The causes of sudden "aging" of erythrocytes are not quite clear. Perhaps, this process is related to some extent to compensatory replacement of erythrocytes, which were lost as a result of hemorrhages, by devicient ones that have already been excluded from the circulation and migrated after trauma into the blood stream again. Nor can it be ruled out that trauma is associated with appearance of some toxic substances in blood, which have a direct effect on the structure of cell membranes of all, or the majority of erythrocytes. Such substances may include histamine, oxidized lipid products and products of protein breakdown [9]. Analogous effects are also observed with a change in blood pH [10], inhibition of glycolysis in erythrocytes [11] and increased insulin concentration in blood [7], i.e., in the presence of various changes in composition of the body's internal environment.

Erythrocyte count and hemoglobin content of rat blood at different times after exposure to impact accelerations (% of initial levels)

Parameter	1st group					2d group					3d group				
	4 h	1 day	2 days	3 days	5 days	4 h	1 day	2 days	3 days	5 days	4 h	1 day	2 days	3 days	5 days
Erythrocyte content	—	100	98	100	—	101	98	98	98	100	102	98	98	94	102
Hemoglobin content	—	100	100	103	—	99	102	104	104	102	97	84	90	90	96

Note: Initial erythrocyte count 4.8 million/m^3 (4.6-5.0) and initial hemoglobin content 13.7 g% (12.7-14.0).

Scott et al. [12], who studied the mechanism of acid hemolysis, expound the hypothesis that the discharge of hemoglobin in this case (as well as, for example, in the presence of paroxysmal noctural hemoglobinuria) is related to the formation of "openings" in the erythrocyte membrane, which are large enough to allow the hemoglobin to escape. Evidently, in the case of severe trauma, conditions are created that favor formation of these "openings" in the erythrocyte membrane and spontaneous escape of hemoglobin. The decrease in blood hemoglobin content against the background of unchanged erythrocyte content, which we noted in the third group of animals, can probably be attributed to this cause. According to the foregoing, severe trauma unquestionably affects the qualitative state of erythrocytes: there is a drastic decrease in their resistance, in particular to acid hemolysis.

On the basis of the demonstrated differences in behavior of the cell system in question, on the whole and with regard to acid hemolysis (lack of changes in the case of factors that do not induce damage; increased chemical resistance of erythrocytes under the influence of factors limiting damage exclusively to lung tissue, which incidentally is interpreted as manifestation of the primary deleterius effect of landing accelerations [3, 13, 14]; drastic decrease in chemical resistance of erythrocytes in the case of severe trauma),

it is concluded that the changes in chemical resistance of erythrocytes are a rather informative indicator for in vivo evaluation of the intensity of effects of impact accelerations on the body, including differentiation between deleterious and nondeleterious exposure.

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EXTERNAL RESPIRATION AND GAS EXCHANGE REACTIONS OF MAN DURING ROTATION ON A SHORT-ARM CENTRIFUGE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 85-86

[Article by O. L. Golovkina, submitted 11 Aug 78]

[Text] Our main objective here was to study the reactions of the human external respiration system and gas exchange during exposure to accelerations and combination thereof with exercise on a bicycle ergometer, using a short-radius centrifuge (SRC).

Methods

We conducted three series of studies: one involving exercise on a bicycle ergometer with a 600 kg-m/min load for 10 min, 3 times, at 10-min intervals for rest; rotation on SRC with accelerations of +1.0, 1.5 and 2.0 G_z for 60 min; rotation on SRC for 60 min with accelerations of +1.0 and +1.5 G_z combined with pedaling on the bicycle ergometer 3 times for 10 min each. Five or six subjects participated in each series. The subjects were in horizongal position. During rotation on the SRC (R = 2 m), the accelerations were in the direction of the head-pelvis axis (Z) and maximum levels thereof were created on the level of the feet. The axis of rotation passed through the subject's nasal bridge. During rotation, braces were placed under his feet so that the subject would not shift in relation to the rotation axis. The bicycle ergometer was secured to the centrifuge for the same purpose. We recorded the pneumotachygram (to determine minute volume of respiration, MV) and rate of cardiac contractions (heart rate, HR). We collected air samples using a modification of the Douglas-Haldane method for subseuqent analysis and calculation of energy expended (EE) and gas exchange. This recording was made after 15 min of rest, prior to the study, during the study and in the 10-min aftereffect period. On the basis of the obtained data, we calculated the oxygen pulse (OP), coefficient of oxygen uptake (OU), oxygen debit (OD) and coefficient of recovery (CR).

Results and Discussion

We failed to demonstrate reliable changes in values of the main parameters of the system of external respiration with exposure to accelerations of

+1.0 G_z, as compared to background data (Table 1). With exposure to accelerations of +1.5 and 2.0 G_z, we observed a reliable increase in HR, MV and EE, as compared to background data and those obtained with +1 G_z.

Table 1. Main parameters of the external respiration system during rotation on SRC ($M \pm m$)

Accelerations, G_z	n	HR/min	MV, ℓ/min	EE, kcal/min	OP, mℓ/beat	OU, mℓ/ℓ
Background	54	70±1,0	11,09±0,22	1,47±0,03	4,39±0,13	27,28±0,34
+1,0	15	70±4,0	10,87±0,28	1,52±0,07	4,50±0,36	28,65±0,69
+1,5	18	80±3,0	12,99±0,59	1,76±0,10	4,53±0,27	27,69±0,64
+2,0	9	84±2,0	12,73±0,38	1,85±0,06	4,54±0,02	29,85±0,19

Note: Here and in Table 2, n refers to number of cases.

Table 2. Main parameters of external respiration system while pedaling on bicyle ergometer and combination thereof with rotation on SRC ($M \pm m$)

Exposure factors	n	HR/min	MV, ℓ/min	EE, kcal/min	OP, mℓ/beat	OU, mℓ/ℓ	OD, mℓ	CR
Bicycle ergometer	30	122±7,0	40,29±1,0	8,13±0,26	13,17±0,79	40,08±1,35	1225±66,3	10,82±0,65
SRC(+1.0 G_z) + bicycle ergometer	18	117±7,0	39,36±0,70	7,09±0,30	13,18±0,53	38,96±1,31	885±66,0	13,92±1,80
SRC(+1.5 G_z) + bicycle ergometer	18	122±7,0	40,26±1,82	7,48±0,44	12,23±0,40	36,75±0,89	950±58,7	12,15±1,18

No changes in OP and OU occurred with all levels of accelerations, as compared to background data. There was no OD after exposure. During the recovery period, all parameters reverted to their base values. According to the subjective evaluation of the subjects, these accelerations are well-tolerated; they do not induce unpleasant sensations or breathing difficulty. This is also confirmed by the fact that there were only insignificant changes in external respiration of the subjects, while OP and OU, which reflect interaction between the external respiratory and circulatory systems, remained unchanged.

Most parameters obtained in the case of combination of rotation on SRC, with accelerations of +1.0 and 1.5 G_z, and pedaling on a bicycle ergometer did not differ reliably from those obtained during pedaling without rotation (Table 2). However, OD constituted 885 mℓ in the tests with rotation, with acceleration of +1.0 G_z combined with pedaling, and 950 mℓ with exposure to 1.5 G_z. These levels were reliably lower than OD during pedaling without rotation (1225 mℓ). As reported by the subjects, the combination of exercise and rotation on the SRC was well-tolerated, and the feeling of fatigue was less marked in this case than when pedaling on the bicycle ergometer without rotation.

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EFFECT OF SHIELDING AGAINST GEOMAGNETIC FIELD ON GLUCOSE-6-PHOSPHATE DEHYDROGENASE ACTIVITY IN THE LIVER OF YOUNG RABBITS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 p 87

[Article by A. V. Shakula and I. Sh. Galeyev, submitted 28 Apr 77]

[Text] Our objective was to study the effect of shielding from the geomagnetic field (GMF) on activity of glucose-6-phosphate dehydrogenase (G6PD), the key enzyme of the pentose-phosphate route of glucose oxidation, in the liver of young rabbits.

Methods

We conducted our studies on 22 month-old rabbits (11 experimental and 11 control) of both sexes. They were taken from two rabbits from the same nest, mated with the same male. The experimental mother rabbit was shielded from GMF during the gestation period and development of the young rabbits up to the age of 1 month. The control female rabbit was exposed to the GMF at the latitude of Leningrad, other conditions being equal.

A triple-layer permalloy screen was used to shield the animals from the GMF. The intensity of the magnetic field was measured with an iron probe ["ferrozondovyy"] nanoteslameter. There was 600-fold attenuation of GMF within the chamber

The animals were decapitated 1 month after birth. A homogenate of the right lobe of the liver, prepared in 0.15 KCl (1:8) was centrifuged for 60 min at 25,000 G. G6PD activity was determined in the supernatant by the method of Kornberg and Horecker [1], using an SF-16 spectrophotometer (wavelength 340 nm); protein was assayed according to Lowry [2]. The obtained results were submitted to statistical processing using the U criterion of Wilcoxson-Mann-Whitney.

Results and Discussion

GPDH activity constituted a mean of 0.174±0.018 μM $NADP \cdot H_2$/mg protein/min in control animals and 0.088±0.013 μM ($P<0.001$) in experimental ones. The

reliable decline of G6PD activity could be indicative of decreased biosynthesis of enzymes of the pentophosphate route, or reduction of their activity in the case of shielding from the GMF.

These are preliminary data, and further details are required.

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BLOOD COAGULATION AND TISSULAR FACTORS OF BLOOD CLOTTING IN HEPARINIZED RABBITS SUBMITTED TO HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 87-89

[Article by L. P. Sviridkina, V. I. Inchina and Yu. I. Grinevskaya, submitted 22 Mar 77]

[Text] In the opinion of a number of researchers [1-3], the decrease in muscular activity of cosmonauts plays the main role in the genesis of hemodynamic disturbances, which appear after space flights. Many works have appeared in the last few years concerning the influence of hypokinesia on different organs and systems; however, the information about changes in blood clotting related to limited movement is rather contradictory [4-13], whereas there is none at all in the literature concerning the state of the tissular system of hemostasis. Some investigators report an increase in blood clotting potential at the early stages of hypokinesia [9-12]. On this basis, we decided to study the blood clotting system and coagulant properties of the wall of the aorta, venae cavae and myocardium during brief, strict immobilization of rabbits against the background of giving them heparin, which has a marked hypocoagulant action.

Methods

This study was conducted on 44 male chinchilla rabbits weighing 2-3 kg. They were immobilized by the method of V. V. Tyavokin [14]. For 7 days, the experimental animals (11 rabbits) were given heparin intramuscularly, at the rate of 1500 active units/kg weight twice a day during hypokinesia (this dose maintains persistent hypocoagulemia in intact rabbits). Fourteen animals served as a control; they were immobilized for 7 days without heparin. We tested blood clotting in experimental animals before and after hypokinesia. In evaluating the tissular system of hemostasis, the results obtained from examination of tissues of 19 intact rabbits served as a second control. We used conventional methods to study the coagulant and fibrinolytic properties of blood and tissues [15]. The results of these studies were submitted to processing by the method of variational statistics for interrelated and noninterrelated parameters. In addition, we took EKG's on the animals before and after hypokinesia.

Results and Discussion

Heparin induces persistent hypocoagulemia and prevents hypercoagulation under the influence of 7-day hypokinesia. Thus, whole blood clotting time increases by 21.4%, as compared to base level, and by 3.4 times as compared to the levels obtained in rabbits submitted to hypokinesia alone. Plasma heparin tolerance decreases by 6.2 and 105%, respectively; antiheparin activity decreases to one-half the base level. The overall thromboplastic properties of blood diminish in heparinized animals, prothrombin time increases. Heparin increases the anticoagulant potential of blood, increasing thrombin time by 2.6 times. The concentration of free heparin increases by 3.6 times in the course of the experiment. Hypokinesia increases blood fibrinase activity. Heparin does not have an appreciable effect on this parameter. The fibrinogen level, assayed in blood by the method of Kumine and Layonas as modified by G. A. Krasovskaya [16], rises from 98 to 222 mg% in animals that are immobilized and heparainized. This increase is less marked under the influence of hypokinesia alone (187 mg%). At first glance, the impression is gained that heparin increases the amount of fibrinogen. However, our previous studies established that there is a drastic increase in blood fibrinogen (to 224 mg%) at the earlier stages of hypokinesia (3 days). Evidently, heparin, which prevents coagulation, preserves hyperfibrinogenemia under hypokinetic conditions. Perhaps elimination of the inhibitory effect of hypokinesia on fibrinolysis is one of the mechanisms of this effect of the anticoagulant. In heparinized animals, fibrinolytic activity of blood is 2.3 times higher than the base data and 3 times higher than in rabbits that were not given heparin. Administration of heparin not only fails to eliminate the increase in functional activity of thrombocytes, which occurs under the influence of immobility, but even enhances it.

The tissular changes are varied. Thromboplastic properties of the aorta and myocardium do not change in heparinized animals. Heparin does not prevent decrease in activity of tissular thrombokinases in the venae cavae. There is a decrease in tissular capacity to neutralize heparin under the influence of the anticoagulant; however, tissular antiheparin activity increases.

When heparin is given against the background of restricted movement, it lowers the levels of enzymes of the prothrombin complex in the aorta and myocardium, but raises them in veins. It induces an even greater decrease in anticoagulant potential of the aorta and myocardium than hypokinesia; however, it leads to some increase thereof in the veins.

Anticoagulant injections reduce the fibrin-stabilizing properties of the aorta and venae cavae. Fibrinase activity remains high in the myocardium.

Fibrinolytic properties of tissues were studied by the euglobulin method as modified by Skipetrov [17]. The tissues of intact rabbits have low fibrinolytic activity. There are no stimulators of fibrinolysis in the intima and media of the aorta, and they are demonstrable only in the adventitia. The low fibrinolytic potential of rabbit tissues is attributable to the presence of strong plasminogen inhibitors. Heparin raises the levels of fibrinolysis

activators in all tissues examined, and it lowers only negligibly the levels of inhibitors. For this reason, there is negligible increase in overall fibrinolytic activity after administration of the anticoagulant.

Hypokinesia induces significant changes in bioelectrical activity of the myocardium. Thus, a change in T wave (flattening, inversion) and dynamics of size of P wave, as well as shifting of S-T interval from the isoelectric line, were demonstrated in 13 out of the 16 rabbits examined. Signs of myocardial infarction were recorded in two cases. Heparin worsened significantly coronary circulation: at the end of the experiment; the EKG of over half the animals was unchanged.

Thus, by lowering the hemocoagulation potential and increasing fibrinolytic activity of blood and tissues, heparin prevents development of a thrombogenic situation during hypokinesia. Enhancement of antiheparin properties of tissues and reduction of the anticoagulant potential of the cardiovascular system apparently constitute a factor that prevents hemorrhagic complications. Evidently, the same factor increases the functional capacity of thrombocytes. Improvement of indices of bioelectrical activity of the myocardium, which is probably the result of faster transcapillary exchange of oxygen [18], decreases sensitivity of vessels to catecholamines [19] and the vasodilating effect of heparin [20], is indicative of the beneficial effect of this anticoagulant on tissular trophics.

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THIRD SYMPOSIUM ON MOTION SICKNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian No 4, 1979 pp 89-90

[Article by G. L. Komendantov and A. G. Bystrova]

[Text] The third symposium on the problem of motion sickness was held in Moscow, on 21-22 November 1978, in accordance with the work schedule of the section of aviation and space medicine of the Moscow department of the All-Union Society of Physiologists.

A total of 173 people participated in the work of the symposium, referable to scientists, practicing physicians and specialists from 18 cities of the Soviet Union.

Prominent specialists in the field of aviation medicine delivered papers: B. S. Alyakrinskiy, I.I. Bryanov, V. N. Barnatskiy, Yu. A. Vasil'yev, M. D. Yemel'yanov, Ye. Ya. Kaplan, V. A. Kislyakov, L. A. Kitayev-Smyk, G. V. Kovalev, A. V. Korobkov, N. I. Kostrov, V. Ye. Koryukin, E. V. Lapayev, S. S. Markaryan, A. D. Matveyev, O. Ya. Plenis, K. A. Pimenova, B. I. Polyakov, N. A. Razsolov, S. I. Stepanova, P. I. Syabro, V. V. Usachev, A. A. Shipov, I. Ya. Yakovleva, A. I. Yarotskiy and others.

The agenda topics were pathogenesis of motion sickness, questions of expertise and pharmacological prevention.

In his opening remarks at the symposium, Prof G. L. Komendantov, chairman of the organizing committee and laureate of the USSR State Prize, commented on the ever increasing social significance of the problem of motion sickness in connection with scientific and technological progress, as well as changes in work structure, progressive decrease in share of physical work done by modern man. This is associated with decrease in statokinetic stability which, in turn, leads to decrease in nonspecific systemic resistance and susceptibility to disease. For this reason, modern mankind has been confronted with the tremendous task of developing appropriate preventive measures.

Prof M. D. Yemel'yanov shed light on some new aspects of pathogenesis of motion sickness. It was discussed as a special case of a neurodystrophic process.

In their paper, N. I. Kostrov and O. Ya. Plenis submitted some interesting material on distinctions of man's adaptation to long-term flight service. The new biorhythmological direction of work on motion sickness was reflected in the papers of B. S. Alyakrinskiy, S. I. Stepanova and A. A. Koreshkov. The paper of V. D. Yustova contained data indicative of the need for quantitative evaluation of equilibrium function in medical certification of fitness for flying duty.

The paper of I. I. Bryanov et al. submitted material characterizing onset and development of motion sickness during spaceflights and in the readaptation period. It was demonstrated that resistance to motion sickness is determined to a significant extent by the distinctions of neurohumoral regulation. In these authors' opinion, "sensory conflict" is the main pathogenetic mechanism.

A new aspect of analysis of function of the vestibular analyzer as an information processing and effector control system was described by Prof V. A. Kislyakov.

The paper of V. V. Usachev submitted the results of a many-year study of correlations between hemodynamics and vestibulovegetative stability.

On the basis of analysis of the literature and his own material, E. V. Lapayev arrived at the conclusion that the existing methods of modeling the etiology of motion sickness, which are currently used in medical certification, are probably too strenuous, and this leads to frequent rejection of flying school candidates. The expert certification process should assess not only vegetative stability, but stability of professional flying activity. The latter statement was in agreement with the contents of the paper of O. P. Yakovlev.

The papers of Prof P. I. Syabro, Prof G. V. Kovalev et al., V. N. Barnatskiy, I. I. Voynova and Ye. Ya. Kaplan (dealing with pharmacological prevention of motion sickness) were very interesting.

Apparently, dibazol [benzimidazole], phenylbut and other derivatives of γ-aminobutyric acid, as well as combinations of products with physiological procedures (creation of dominant foci, etc.) (I. I. Bryanov, P. I. Syabro, G. V. Kovalev and others), are the most effective agents at the present time.

Current scientific requirements were described for the process of evaluating products for the prevention and treatment of motion sickness at different stages: in experiments on animals, clinical trials of drugs (Ye. Ya. Kaplan, I. I. Voynova and others).

The paper of V. N. Barnatskiy submitted new data on the use of sodium hydrocarbonate for the prevention and treatment of seasickness. A. G. Bystrova proved, in experiments on animals, that sodium hydrocarbonate attenuates the process of summation of reactions in simulation of motion sickness, thereby disclosing one of the mechanisms of the beneficial effect of sodium hydrocarbonate on the process of motion sickness.

Lively interest was displayed in the report of I. S. Maysheva, who studied motion sickness under real conditions among passengers of modern civil aviation liners. It was established that 7 to 10% of the passengers suffer from motion sickness, 9-10% request pharmacological agents aboard an aircraft and about 1.5% take them on their own.

The following participated in the discussion: Yu. A. Vasil'yev, S. S. Mar Markaryan, P. I. Syabro, M. D. Yemel'yanov, M. S. Denisyuk, E. V. Lapayev, N. I. Arlashchenko, V. Ye. Koryukin, M. B. Zabutyy, B. I. Polyakov and V. F. Solodovnik.
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